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A THEORY OF THE ORIGIN AND EVOLUTION OF THE AUSTRALIAN MARSUPIALIA.

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INTRODUCTION.

ALTHOUGH considerable attention has been given to the discussion of the family and generic affinities of the Australian marsupials from a systematic standpoint, until very recently the phylogenetic aspects of the question have been generally neglected. On this account, and also from the fact that little information has been forthcoming either from paleontology or geographical distribution, it has not been possible, up to the present time, to form an adequate conception of the origin of the fauna and its phylogenetic relationships.

The present paper is the result of an attempt to outline a plan of evolution for the group by comparing the adaptive modifications of the teeth and feet with those of placental mammals, in which the course of evolution is fairly well known. On account of the difficulties with which the writer has had to contend in having only a small number of marsupial types at his disposal, the present plan is advanced simply as a working

hypothesis. A fuller discussion of the question will be published in the course of a few months.

The fact was noticed long ago by Cuvier, and has been commented upon by many zoölogists since, that the marsupials of Australia assume much the same rôles in nature as are taken by placentals in other parts of the world, and that they show extensive resemblances to the latter in many features of their external organization. It is only within the last few years, however, in fact since the evolution of the placentals has come to be understood, that the exact significance of these resemblances has been at all apparent. Knowing that during the Tertiary period placental mammals have undergone a progressive development, or, in other words, an adaptive radiation, from diffuse or collective types, by which not only their minor but also their ordinal characters have been established, the question now suggests itself, Have not the Australian marsupials undergone an entirely similar or, in other words, a *parallel* radiation?

The possibility of such a condition has already been suggested by Osborn ('99a), who recognizes several mammalian radiations, including among them a marsupial radiation for Australia, and remarks as follows: "We mark the fact that the above radiations are all of ordinal rank, for the marsupial radii, although termed families, are adaptively equivalent to several placental orders."

Examining the composition of the group somewhat in detail, we find many indications of such a parallel radiation. Two classes of facts may be specially noticed in this connection. First, the Australian marsupials constitute a very homogeneous group; although differing widely in extremes, not only the various genera of a family but also the families themselves are connected by almost insensible gradations of structure. Second, the adaptive modifications of their teeth and feet are very similar to those of placental mammals either at the present day or during their progressive development in the Tertiary period, and they bear the same relation as do those of placentals to the general primitiveness of the animals in which they occur.

The Australian marsupials, therefore, show no signs of a

composite structure such as might be expected if they represented migrated portions of the fauna of another continent, or, again, if they were of polyphyletic origin. Except in a very few instances, they show no signs of degeneration; as a group they are, like the placentals, progressive throughout. In short, the only satisfactory explanation that can be given for the homogeneous character of the group and their adaptive resemblances to placentals seems to be that they have undergone an entirely similar radiation under similar conditions, that it has proceeded from a single sharply marked ancestral type, and that the center of radiation has been the Australian region itself.

Assuming that a similar radiation has taken place in marsupials and placentals, it will be apparent that a plan of evolution may be constructed for the former by inference from that of the latter. Thus, by noting the sequence of events in the development of the adaptive modifications of the teeth and feet in placentals during the Tertiary period, we may infer a similar sequence in those of marsupials, and in this way determine their probable course of evolution in these structures, and also the characters of their stem form.

The Probable Characters of the Marsupial Stem Form.

Dentition. — In the case of the placental mammals, progressive evolution in dentition is accompanied by a reduction of certain of the teeth and by an elaboration of certain others, notably the molars. Unreduced dentitions with slightly elaborated teeth are therefore primitive. But just as in formulating such a law it is necessary to exclude those forms whose dentition, while being of primitive aspect, is not typically primitive, but primitive through degenerate specialization (Delphinidæ, Otariidæ), it is also necessary in applying it to the case of the marsupials to exclude similarly conditioned forms of that series.

The only marsupials which call for consideration in this respect are the forms Myrmecobius and Notoryctes.[1] There

[1] Tarsipes appears to be degenerate in dentition, but the teeth are not primitive in aspect.

are two reasons for regarding these as degenerate in dentition. First, there is a prototypal tooth pattern in marsupials, which is shared alike by the Didelphyidæ and the insectivorous members of the Dasyuridæ, and of which the tooth patterns of the carnivorous Dasyuridæ and the Peramelidæ are undoubtedly progressive modifications, while those of Myrmecobius and Notoryctes are aberrant. The tooth patterns of both of these forms are more primitive in aspect than those of any other of the Australian forms, but the animals are specialized in other respects. Thus Myrmecobius is typically dasyurid in foot structure and in its incisor formula of $\frac{4}{3}$, while Notoryctes, according to Dollo ('**99**), is specialized in a phalangerine direction in foot structure. Second, both Myrmecobius and Notoryctes are ant-eating forms,[1] such animals being usually degenerate in dentition, judging from Echidna and the placental Myrmecophagidæ and Manidæ, in which the teeth have been entirely lost.

Excluding Myrmecobius and Notoryctes, we find the primitive dental characters of marsupials distributed as follows :

The least reduced dentition is found in the Peramelidæ, where the formula is : $i.\frac{5}{3}$, $c.\frac{1}{1}$, $p.\frac{3}{3}$, $m.\frac{4}{4}$.[2]

The least elaborated molar teeth are found in the insectivorous members of the Dasyuridæ. The upper teeth (Pl. I, Fig. *d*)[3] are triangular in shape, with three main cusps (protocone, paracone, metacone)[4] and an outer row of styles. There are no conules at the base of the protocone, such as are commonly met with in placental types. The metacone exceeds the paracone in size, and its posterior border is produced into a trenchant spur. The lower teeth (Pl. II, Fig. *d*) are of the

[1] For habits of Notoryctes see Stirling ('**91**, p. 158) and Spencer ('**96**, p. 50, Mammalia).

[2] Or $(m)i.\frac{5}{3}$, $mc.\frac{1}{1}$, $mp.$ and $pp.\frac{4}{4}$, $m.\frac{3}{3}$, following Lydekker ('**99**). The upper incisor dentition may contain teeth of both series.

[3] This type might be more appropriately illustrated by the teeth of Phascologale, Sminthopsis, or Antechinomys, *Dasyurus viverrinus* being more carnivorous in habit. Thomas, however, remarks that the teeth of the three former genera resemble one another very closely, and differ only from those of Dasyurus in being more acutely cuspidate. See Thomas ('**88**, pp. 273, 298, 309).

[4] Following the nomenclature of the tritubercular theory. See Osborn ('**88**, '**91**).

tubercular sectorial pattern, with a main triangle bearing three cusps (protoconid, paraconid, metaconid) and an antero-external shelf, and a posterior heel bearing one outer (hypoconid) and two inner (entoconid and hypoconulid) cusps.

Foot Structure.[1] — In placental mammals, progressive evolution in foot structure, beautifully illustrated in Tertiary Ungulata, is accompanied by a reduction of certain of the digits, and by an elaboration of certain others, the evolution proceeding from an ideal pentadactyl condition, such as is seen typically in the Eocene Creodonta. Among the Australian marsupials the nearest approach to the ideal pentadactyl type is seen in certain members of the Dasyuridæ (Pl. III, Fig. *d*). The hallux is opposable but slightly reduced, while the remaining digits are normal.

Summing up the above results, we may make the general statement that the marsupial stem form possessed the following characters, or more primitive ones: Dental formula, $i.\frac{5}{3}, c.\frac{1}{1}, p.\frac{3}{3}, m.\frac{4}{4}$. Upper molar teeth triangular, with three main cusps and an outer row of styles; metacone exceeding paracone, its posterior border produced into a trenchant spur; no conules at the base of the protocone. Lower teeth with anterior triangle bearing three cusps and an antero-external shelf, and posterior heel bearing one outer and two inner cusps. Foot with hallux completely opposable, the remaining digits normal.

The fact will now be apparent that the above prototypal characters are not found associated in any Australian form. All of the Australian marsupials are derived types. On the other hand, with one exception they are all found in the American Didelphyidæ. The one exception refers to the presence in the latter of four instead of three lower incisors, and in this respect the Didelphyidæ are more primitive. The molar tooth patterns of the stem form are almost exactly reproduced in those of the Oligocene Opossums (Peratherium) (Pls. I and II, Fig. *a*).[2]

[1] This refers throughout to the pes in the case of the marsupials.

[2] In the specimen from which these diagrams were taken (*Peratherium fugax* Cope) the outer parts of the upper molars are worn, so that, although there is a conspicuous external ridge, the presence of styles cannot be affirmed. *Cf.* Cope ('84, Pl. LXII, Fig. 2*a*).

As regards the modifications of the teeth and feet, therefore, the Didelphyidæ exhibit characters which are ancestral to those of the Australian marsupials. The question now arises as to whether or not they are ancestral in other respects. The opportunity has not yet presented itself to the writer of examining the case in detail, so that only a few examples will be given here. As was pointed out in 1880 by Brass, the complex modifications which result in the formation of the peculiar median vagina in specialized marsupials are seen in their incipient stages in the Didelphyidæ, where the two vaginæ bend toward one another in the middle line. Passing onwards from the Didelphyidæ every gradation is met with, until the final stage is reached in the Macropodidæ.

Again, taking the case of the marsupium, the anteriorly directed opening of this structure, as seen in the Phalangeridæ and Macropodidæ, and the posteriorly directed opening, as seen in the Peramelidæ and Notoryctidæ, are obvious departures from such a type as is seen in the Didelphyidæ and Dasyuridæ, in which the opening is directed vertically downwards.

Finally, taking the case of the tail, which is an adaptive structure of the greatest importance in marsupials, it is entirely probable that the hairy, non-prehensile condition, where it occurs in the Australian forms, has been derived from a naked, scaly, prehensile one, such as is seen in the Didelphyidæ. Thomas ('88) describes for the Dasyuridæ, in which the tail is hairy and never prehensile, a scaly condition in various genera, among them *Phascologale wallacei*, *P. flavipes*, and *Sminthopsis leucopus*. A scaly tail, which, according to Thomas, is said to be also prehensile, is found in *Perameles broadbenti* among the Peramelidæ. Every grade of prehensilism is met with among the Phalangeridæ; and, finally, among the Macropodidæ, a scaly tail is found in *Hypsiprymnodon moschatus*, and a prehensile one in the various species of Bettongia.

The above facts, when added to the evidence of the teeth and feet, suggest strongly a former connection of the Didelphyidæ with the Australian marsupials, and although, in attempting to express such a connection phylogenetically, it is a natural procedure to regard the original members of each

group as the descendants of a common stock, the Didelphyidæ are so primitive that it is scarcely possible to regard them, as a family, otherwise than ancestral.[1]

The Evolution of the Teeth in Australian Marsupials.

It has already been mentioned that progressive evolution in dentition, in the case of the placental mammals, is accompanied by a reduction of certain of the teeth and by an elaboration of certain others, notably the molars. The researches of Cope, Osborn, and others have shown that in the evolution of the molar teeth the elaboration proceeds from a trituberculate condition in the upper series, and from a quinquetuberculate or sexituberculate condition in the lower series. These types are exemplified in the teeth of the primitive Creodonta of the early Eocene (Protochriacus, Oxyclænus, etc.).

[1] This involves the question of the limitations of the family Didelphyidæ. Lydekker ('**96**, p. 109), while assigning the didelphyid incisor formula to the ancestors of the Dasyuridæ, speaks (p. 55) of the Didelphyidæ and Dasyuridæ as descendants of a common stock. Spencer ('**96**, p. 188, Summary) speaks of a primitive (South American) group giving rise to the Didelphyidæ of America on the one hand, and to the early Australian types on the other. Ameghino ('**93**, p. 16) regards the family called by him Microbiotheriidæ as ancestral to the Didelphyidæ and to the Australian Dasyuridæ. In the writer's opinion it will not be found advisable ultimately to regard the Didelphyidæ as a modern derived group, but that, when the actual ancestors of the Australian forms are identified, it will probably be found necessary to extend the family Didelphyidæ to include them. Two reasons for this view may be noted. First, the Oligocene forms of Europe and North America have already been included in the existing American family; in other words, we identify as Didelphyidæ forms which existed at about the time when the Australian fauna probably arose. Second, the family Didelphyidæ, as at present limited, is not equivalent to any one of the four typical families of Australian marsupials, the latter being much more comprehensive. The diversity of organization which is met with among the Dasyuridæ in the genera Phascologale and Thylacinus, among the Phalangeridæ in the genera Phalanger, Phascolarctos, and Tarsipes, among the Macropodidæ in the genera Hypsiprymnodon and Macropus, is absolutely without parallel among the Didelphyidæ. If, therefore, the integrity of the Australian families is to be retained, — and there is every reason for believing that they are natural groups, — there are good grounds for extending the family Didelphyidæ to include their own ancestors and those of the Australian forms, if the latter, as they probably did, possessed the main didelphyid modifications of the teeth and feet, even while differing in other minor details. The Microbiotheriidæ of Ameghino may be a case in point.

From this point onwards development takes place along two main lines. In one case the outer cusps of the teeth from being tuberculate become laterally compressed and trenchant, giving rise to the carnivorous modification, seen typically in the specialized Creodonta (Oxyæna, Hyænodon, Oxyænodon, etc.). In the other case the primitive tooth pattern is entirely changed; the upper teeth become quadritubercular by the addition of a postero-internal cusp (hypocone), while the lower teeth also become quadritubercular by the reduction of the most anteriorly placed cusp (paraconid), and the intermediate cusp of the heel (hypoconulid). In this way a primarily omnivorous modification is instituted, which is seen in its constructive stages in the Eocene Condylarthra (series Protogonodon, Euprotogonia, Phenacodus, and various separate genera).

From the typically quadrituberculate condition evolution proceeds in two directions, both leading to the herbivorous modifications of the Ungulata. In one series the cusps of both upper and lower teeth become crescentic, producing the condition characteristic of the Artiodactyla; while in the other they become lophoid, producing the complex modifications of the Perissodactyla. The latter evolution is beautifully illustrated in passing from the Eocene genera (Hyracotherium, Systemodon, etc.) to the modern types.

If, now, we arrange the teeth of the Australian marsupials according to the above placental plan, we obtain such a result as is represented diagrammatically in Pls. I and II. The primitive trituberculate, tubercular sectorial type is here represented by the teeth of *Dasyurus viverrinus* (Fig. *d*). As indicated elsewhere in a footnote, this would be more appropriately illustrated by the teeth of one of the purely insectivorous forms of the Dasyuridæ (Sminthopsis, Antechinomys, Phascologale).

The carnivorous line above mentioned is, in the case of the Australian marsupials, entirely confined to the family Dasyuridæ, and it culminates in the Tasmanian wolf (*Thylacinus cynocephalus*). The teeth of this animal are represented in Pls. I and II, Fig. *g*; they show all the essential characters of those of Dasyurus, except that in the lower teeth the metaconid is absent. The progressive carnivorous modification is, in the

upper molars, a conversion of the paracone and metacone into cutting blades, and a reduction of the outer styles, which are here represented by very inconspicuous tubercles. In the lower teeth the progressive modification is a conversion of the paraconid, protoconid, and hypoconid into cutting blades, and a reduction of the metaconid, hypoconulid, and entoconid.

Turning to the second stem, leading to the omnivorous and herbivorous modifications, we find the first stage represented in the teeth of the Peramelidæ. The upper molars of *Perameles nasuta* (Pl. I, Fig. *e*) show all the essential characters of those of Dasyurus, but in addition they show an incipient hypocone. In the third molar the hypocone is not very pronounced, and the tooth is triangular; but in the second molar the hypocone is well developed, and the tooth is now quadrate. Thomas ('88, p. 220) describes the triangular and quadrate modifications as characteristic of the family. The upper molars of the Peramelidæ parallel, in a general way, those of the Condylarthra above mentioned. The lower molars of *Perameles nasuta* (Pl. II, Fig. *e*) resemble still more closely those of Dasyurus, the omnivorous modification being only apparent in the posterior heel, where the hypoconulid is reduced.

The completed omnivorous modification is doubtless to be met with in the Phalangeridæ. Unfortunately, only two examples of this family have been available to the writer, namely, *Trichosurus vulpecula*, which is highly specialized, and *Petauroides volans*. The teeth of the latter animal are represented in Pls. I and II, Fig. *f*. Although they illustrate the completed quadrituberculate condition, they are only approximately transitional; the hypocone is completely formed in the upper molars, and the paraconid is reduced in the lower molars; but the antero-external shelf, which is prominent in the lower teeth of the Peramelidæ and Dasyuridæ and very conspicuous in those of the Macropodidæ (Pl. II, Fig. *i*), is here absent, and there are no traces of external styles in the upper teeth.

The selenoid modification of the cusps, which is so widely represented in the artiodactyl Ungulata, appears to be confined to the single form Phascolarctos (Pls. I and II, Fig. *j*) among the marsupials, but the lophoid modification is widely represented

in the Macropodidæ (Pls. I and II, Fig. *i*). The incipient stages are seen in the teeth of the specialized Phalanger, *Trichosurus vulpecula* (Pls. I and II, Fig. *h*), and also in those of *Hypsiprymnodon moschatus* (Macropodidæ). It is of interest to note that the lophoid modification is accompanied by a hypsodont condition of the crown in the Macropodidæ, as in the perissodactyl Ungulata.

THE EVOLUTION OF THE FEET IN AUSTRALIAN MARSUPIALS.

It was pointed out by Huxley in 1880 that none of the Australian marsupials possess a normal pentadactyl pes, that wherever the hallux is present it presents an extensive movement of adduction and abduction; in other words, that the marsupial foot is typically prehensile.

Quite recently a careful study of the foot structure of marsupials has been made by Dollo ('99), who endeavors to demonstrate a derivation of all recent forms from arboreal ancestors. Dollo has indicated all the important adaptive modifications in Australian marsupials, although he has not discussed their phylogenetic significance, so that all that is necessary in the present paper is to arrange his types into a phylogenetic series, in accordance with his interpretations and the general plan noted above for the placentals.

Dollo has shown that the arboreal marsupials present successive stages of arboreal adaptation, following which the foot becomes more and more modified. Thus, beginning with the Didelphyidæ (Pl. III, Fig. *a*), the foot is provided with an opposable hallux, and the remaining digits are normal. In the Phalangeridæ (Fig. *b*) the hallux is again opposable, but in addition the fourth digit is enlarged, and the second and third are reduced and syndactylous. Finally, in one member of the Phalangeridæ, Tarsipes (Fig. *c*), there is, in addition to all of these arboreal characters, a recession of the claws of the fourth and fifth digits. It is thus possible to recognize an arboreal line of evolution such as is represented in Pl. III, *a–c*.

Among the terrestrial or semi-terrestrial marsupials, all of the forms, except the specialized members of the Dasyuridæ,

show some of these arboreal characters, indicating that up to a certain stage they have been arboreal in habit. It is thus a simple matter to arrange them in collateral groups according to the stage at which their terrestrial evolution began. Such an arrangement as this is represented diagrammatically in Pl. III, in the side lines passing off from the main arboreal line *a–c*. The first series to be given off is that of the Dasyuridæ. In the least modified members of this family the animals are still arboreal, and the foot (Fig. *d*) is like that of Didelphys (Fig. *a*), except that the hallux is slightly reduced. As Dollo has pointed out, it is possible to recognize a complete series here, following which the hallux becomes gradually reduced and finally obliterated (*e*).

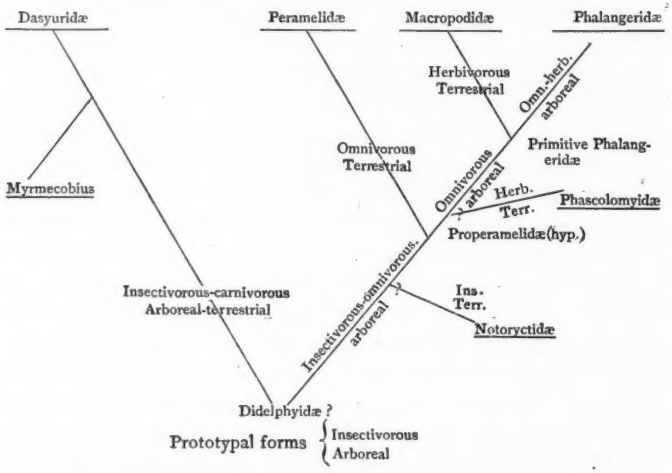
Two other terrestrial offshoots, which parallel one another, and arise from the main arboreal line at the phalangerine stage, are represented by the Peramelidæ and Macropodidæ. In both of these the evolution is cursorial as well as terrestrial, and is accompanied by a reduction of the hallux and an enormous enlargement of the fourth digit, so that the foot becomes functionally monodactyl. The extremes of structure in these lines are, as Dollo has indicated, in the Peramelidæ *Perameles doreyana* (Fig. *g*) and *Peragale leucura* (Fig. *h*) and in the Macropodidæ *Hypsiprymnodon moschatus* (Fig. *i*) and Macropus (Fig. *j*).

Another terrestrial offshoot is represented by the Phascolomyidæ (Fig. *f*), although the relations of this branch are doubtful. The hallux is reduced in these animals as in other terrestrial forms. With respect to the remaining digits, the foot appears to be transitional between that of the Didelphyidæ and that of the Phalangeridæ, the second and third digits not being so reduced as in the latter family. The difficulty arises here as to whether or not the second and third digits, from being fully reduced, as in the Phalangeridæ, have been secondarily enlarged. Such a condition would appear to be not improbable in slow-moving animals, such as the wombats ; in the other animals which have passed through a phalangerine stage the tendency towards monodactylism has doubtless prevented the second and third digits from becoming secondarily functional.

For Notoryctes Dollo describes a slight syndactylism and reduction of the second and third digits, which points out this form as still another offshoot of the main arboreal line.

GENERAL REMARKS ON THE EVOLUTION OF AUSTRALIAN MARSUPIALS.

When we compare the plan of evolution as determined by the structure of the teeth with that determined by the structure of the feet, we note the fact that they practically coincide. Thus there are two lines leading from the prototypal forms, one of them showing an insectivorous-carnivorous and an arboreal-terrestrial evolution leading to the Dasyuridæ, the other showing an insectivorous-omnivorous and a progressive arboreal evolution leading to all the remaining marsupial families.



Following the former line, there appears to have been a typical evolution in all forms except Myrmecobius, which, as noted above, is probably degenerate in dentition.

Following the omnivorous arboreal line, we find that one of its stages has been obliterated, being unrepresented among existing forms. The characters of other forms, however, leave

no doubt as to its composition. Thus the Phalangeridæ present a typical arboreal modification of the foot, combined with advanced omnivorous and herbivorous modifications of the teeth, while the Peramelidæ present a terrestrial modification of the phalangerine foot, combined with a primitive omnivorous condition of the teeth. There must, therefore, have existed at some time, if the present plan is reliable, a series of forms such as is represented in the general diagram on p. 256 as Properamelidæ (hyp.), consisting of animals which combined a phalangerine type of foot with a primitive omnivorous dentition. These animals would have given rise to the Peramelidæ by a terrestrial modification of the foot, and to the Phalangeridæ by a more completely omnivorous and finally herbivorous modification of the teeth.

From the phalangerine stem, after the omnivorous modification was established, there was apparently given off a branch to the Macropodidæ, with a trend of evolution from arboreal to terrestrial, and from omnivorous to herbivorous. The herbivorous modification reaches its greatest development in this family.

The phylogenetic positions of the Phascolomyidæ and Notoryctidæ, as indicated in the general plan, are by no means certain. In the case of the former, the difficulty in interpreting the foot structure has already been commented upon. The unworn molar teeth of these animals are said by Krefft ('75) to be quadrituberculate. If such is the case, it would appear probable that they arose from the omnivorous arboreal stem after the Peramelidæ were given off, and that there has been a secondary enlargement of the second and third digits.

In the case of the Notoryctidæ the writer has not been able as yet to decide definitely the cusp homologies in the upper teeth, but the lower are undoubtedly tritubercular; as indicated above, the dentition is probably degenerate. Combining this interpretation with the evidence of arboreal characters in the foot, it would seem probable that Notoryctes arose from the arboreal omnivorous line somewhere near the Properamelidæ.

A DIDELPHYID ORIGIN IN THE LIGHT OF GEOGRAPHICAL DISTRIBUTION.

In discussing the question of the origin of the Australian marsupials it is apparent that, apart from the evidence derivable from the organization of existing types, any opinions which are expressed on the subject must take into consideration the present and past geographical distribution of marsupials, the manner in which the ancestral forms gained access to the Australian region, and the time at which their entry was effected.

Within the last twenty-five years several attempts have been made to connect the Australian marsupials with the extinct types of different horizons in other countries, and to explain in this way the conditions of their origin. Thus, in 1876, Wallace suggested a possible relation to the Jurassic forms of the northern hemisphere.[1] Concerning this he speaks as follows: "As, however, no other form but that of the Didelphyidæ occurs there (in Europe) during the Tertiary period, we must suppose that it was at a far more remote epoch that the ancestral forms of all the other marsupials entered Australia; and the curious little mammals of the Oölite and Trias offer valuable indications as to the time when this really took place."[2] . . . "It was probably far back in the Secondary period that some portion of the Australian region was in actual connection with the northern continent, and became stocked with the ancestral forms of marsupials."[3]

In 1882 Cope, in commenting upon the ancestry of Thylacoleo, placed this form in the family Plagiaulacidæ of the northern hemisphere, and regarded the latter as related to the Australian Macropodidæ through a hypothetical ancestor Tritomodon. There is, however, no valid evidence in favor of this view.

[1] Haeckel has recently endeavored to express such a relation phylogenetically by deriving all of the modern marsupials from a Jurassic group of Prodidelphia, which he regards as also ancestral through certain of its members, the Amphitherida and Amblotherida, to the placentals. See Haeckel ('**95**, p. 471).

[2] Wallace ('**76**, vol. ii, p. 253).

[3] *Ibid.* (vol. i, p. 465).

By far the most complete discussion of the question, from all points of view, is that given by Lydekker ('96) in his *Geographical History of Mammals.* Lydekker, while agreeing with Wallace as to the northern origin of the Australian fauna, fixes its time of entry at a much later period, namely, at the beginning of the Eocene, on the basis of a possible connection of the ancestors of the Australian Dasyuridæ with those of the Oligocene Didelphyidæ of the northern hemisphere. He remarks as follows (p. 55): "Recent researches have tended to show that the alliance between the Dasyuridæ and the Didelphyidæ is much more intimate than was formerly supposed to be the case. This being so, it is a fairly safe assumption that both families are descended from a single common ancestral stock." . . . "Not improbably polyprotodont marsupials survived in southeastern Asia till the early portion of the Eocene division of the Tertiary epoch, and in this region both Dasyuridæ and Didelphyidæ were differentiated. Representatives of the former family soon afterwards found their way into Australia and New Guinea, while the opossums would appear to have dispersed in one direction into Europe and in the other into North America."

Objection has been taken to this view by Spencer ('96) on account of the difficulty of explaining by it the non-appearance of Didelphyidæ in Australia and the paucity of polyprotodont types in New Guinea, and also on account of the lack of evidence of the former presence of marsupials in Asia.

For a northern origin Spencer substitutes a South-American one taking place in the late Cretaceous through the medium of an Antarctic continent. This idea is also favored by P. L. and W. L. Sclater ('99). Viewing the question from a phylogenetic standpoint alone, Lydekker has recently ('99) suggested the Prothylacinidæ (Sparassodonta of Ameghino) of the South-American Miocene as possibly ancestral to the Dasyuridæ, and Ameghino ('93) regards the family called by him Microbiotheriidæ as ancestral to both the Dasyuridæ and the Didelphyidæ.

Spencer, however, in attempting to derive the Australian fauna, encounters the same difficulty which confronted Lydekker, namely, how to explain the non-appearance of Didelphyidæ

in Australia. Concerning this he remarks as follows (p. 188, Summary): "The only way in which it seems possible to account at once for the presence of forms such as Prothylacinus in the Patagonian Tertiary beds, and the absence of any of the Didelphyidæ in Australia, is to suppose that on the South-American side the connection between the Antarctic land and what is now Patagonia was lost at a time comparatively soon after the early polyprotodonts had passed across, and during which the Didelphyidæ were being developed perhaps in the more northern part of South America."

In the writer's opinion, the difficulty of explaining the absence of the Didelphyidæ from Australia is only an apparent one, which is due to the interpretation of this family as a modern derived group. Reasons have already been given for the elevation of the family to an ancestral position, and if the case is susceptible of proof, no other explanation is necessary to account for their absence from the Australian region than the assumption that they were formerly present and subsequently disappeared. If we imagine the family to have originally gained access to the region, it is not difficult to conceive that, in establishing the foundations of an extremely comprehensive adaptive radiation, especially under the favorable conditions of absolute freedom from competition, they should have thrown aside their distinctive didelphyid characters. And more especially is this conceivable when we realize that the differences of structure separating the Didelphyidæ from the most primitive of the Australian forms (insectivorous Dasyuridæ) are very slight.[1]

Concerning the direction from which the ancestral Didelphyidæ may have entered the Australian region, there is at least some justification for the view that it was from the northward. Lydekker ('96, p. 57) has called attention to the fact that there are marked indications of a faunal affinity of North America and Asia, which points to an interchange of forms between the two continents. This suggests a connection of the Oligocene opossums of Europe with those of North America, and, as Lydekker has pointed out, there may have

[1] *Cf.* Thomas ('88, p. 315).

been a migration of these animals into both countries from a common center in Asia ; on the other hand, there may have been simply a passage of forms *via* Asia. In either case the former presence of opossums on the latter continent would be indicated.

However this may be, the actual evidence at our disposal is very slight, and it is equally conceivable that ancestral Didelphyidæ may have entered by way of Antarctica. This possibility has been suggested by Osborn ('99b), although no preference is indicated by him for either view. As already indicated, the time at which the ancestral marsupials gained access to the Australian region has been estimated by Wallace as "far back in the Secondary," by Spencer as Cretaceous, and by Lydekker as early Eocene. It is probable, however, that these estimates are much too great, and that the time of entry was considerably later. Comparing the marsupial and placental radiations with respect to the modifications of the teeth and feet, we notice the fact that while there is a general correspondence between the most primitive characters of each series, there is no such correspondence between the most specialized ones. The most specialized characters of marsupials are decidedly primitive as compared with the most specialized characters of placentals. To illustrate the case, while the insectivorous members of the Dasyuridæ and the Didelphyidæ approach closely the trituberculate pentadactyl ancestors of the placentals, the Macropodidæ, which are the most specialized of the marsupials, are much more primitive than the most specialized placentals (perissodactyl Ungulata) whose evolution they parallel. The lophiodont teeth of these forms are very similar to those of such persistent primitive types as the Tapiridæ and their immediate ancestors, having none of the complex characters of those of the progressive lophiodont forms (Equidæ and Rhinocerotidæ). The functionally monodactyl, cursorial feet of the Macropodidæ are primitive as compared with the similarly modified feet of the Equidæ. Further, there is the remarkable fact that while the marsupial families have the value of placental orders, it is barely possible to separate them

sharply as families. In fact, they show such a composition as must have existed at some stage of the placental radiation.

Now the Macropodidæ show no signs of being persistent primitive types, and there seems to be no valid reason for assigning to the marsupials a different potential of evolution. The only explanation which may be given for the above facts is, therefore, that the Australian radiation has been of comparatively short duration.[1] And if the placental radiation began in the late Cretaceous or in the early Eocene, as now appears probable, it is unlikely that the marsupial radiation can have begun until well on into the Tertiary. An ancestral association with the Oligocene opossums of the North or even with the Lower Miocene forms of South America is thus not improbable.

As to whether or not the ancestral forms gained access to the Australian region by means of a land connection would appear to be a matter of little consequence if the fauna is of didelphyid origin. Such minute animals as they must have been, judging from the Oligocene forms of the northern hemisphere and the diminutive opossums of South America, might have gained access to the region by transportation in various ways.

In conclusion, the writer wishes to acknowledge his indebtedness to Professor H. F. Osborn of Columbia University for many kind suggestions during the preparation of this paper, and to Professor Allen of the American Museum of Natural History, New York, Professor W. B. Scott of Princeton University, and Professor R. Ramsay Wright of the University of Toronto, for the privilege of examining the marsupial collections of the above-named places.

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[1] This suggests Huxley's statement of twenty years ago: "And I suspect that most, if not all, of the Australian forms are of comparatively late origin." (On the Application of the Laws of Evolution, etc., *P. Z. S.* (1880), p. 656).

BIBLIOGRAPHY.

'93 AMEGHINO, F. Les mammifères de Patagonie. *Revue Scientifique* (Jan. 7, 1893). pp. 13–17. Paris.

'80 BRASS, A. Beiträge zur Kenntniss des weiblichen Urogenitalsystems der Marsupialen. Inaug. Diss. Leipzig.

'82 COPE, E. D. The Ancestry and Habits of Thylacoleo. *Amer. Nat.* Vol. xvi, pp. 520–522.

'84 COPE, E. D. Tertiary Vertebrata. *Report of the U. S. Geological Survey of the Territories.* Vol. iii. Washington.

'99 DOLLO, L. Les ancêtres des Marsupiaux, étaient-ils arboricoles? *Miscellanées biologiques.* pp. 188–203. Paris.

'95 HAECKEL, E. Systematische Phylogenie. 3. Theil. Berlin.

'80 HUXLEY, T. H. On the Application of the Laws of Evolution to the Arrangement of the Vertebrata, and more particularly of the Mammalia. *Proc. Zoöl. Soc.* pp. 649–662.

'75 KREFFT, G. Remarks on Professor Owen's Arrangement of the Fossil Kangaroos. *Ann. Mag. Nat. Hist.* Vol. xv, pp. 204–209.

'96 LYDEKKER, R. A Geographical History of Mammals. Cambridge.

'99 LYDEKKER, R. The Dental Formula of the Marsupial and Placental Carnivora. *Proc. Zoöl. Soc. London.* pp. 922–928.

'88 OSBORN, H. F. The Evolution of Mammalian Molars to and from the Tritubercular Type. *Amer. Nat.* pp. 1067–1079.

'91 OSBORN, H. F. Fossil Mammals of the Wahsatch and Wind River Beds. I. Homologies and Nomenclature of the Mammalian Molar Cusps. *Bull. Amer. Mus. Nat. Hist.* Vol. v, pp. 84–91.

'99a OSBORN, H. F. The Origin of Mammals. *Amer. Journ. Sci.* Vol. vii, pp. 92–96.

'99b OSBORN, H. F. Correlation between Tertiary Mammal Horizons of Europe and America. *Ann. N. Y. Acad. Sci.* Vol. xiii, pp. 1–72.

'99 SCLATER, P. L. and W. L. The Geography of Mammals. London.

'96 SPENCER, B. Report of the Horn Expedition to Central Australia. Part I. September, 1896.

'91 STIRLING, E. C. Description of a New Genus and Species of Marsupialia, "Notoryctes typhlops." *Trans. and Proc. Roy. Soc. South Australia.* Vol. xiv, Part I, pp. 154–187. 1890–1891.

'88 THOMAS, O. British Museum "Catalogue of the Marsupialia and Monotremata." London.

'76 WALLACE, A. R. The Geographical Distribution of Animals. 2 vols. New York.

EXPLANATION OF PLATE I.

Illustrating the patterns of the upper molar teeth in marsupials and their probable phylogenetic relations.

NOTE. — The prototypal form is provisionally represented by Peratherium. Figs. b and c are inserted for comparison.

a. — *Peratherium fugax* Cope.
b. — *Didelphys azaræ* Temm.
c. — *Didelphys virginiana* Kerr.
d. — *Dasyurus viverrinus* Shaw.
e. — *Perameles nasuta* Geoff.
f. — *Petauroides volans* Thos.
g. — *Thylacinus cynocephalus* Fisch.
h. — *Trichosurus vulpecula* Jent.
i. — *Macropus sp.*
j. — *Phascolarctos cinereus* Fisch.

Abbreviations.

Pr. — protocone. *Me.* — metacone.
Pa. — paracone. *Hy.* — hypocone.
St. — external styles.

FIG. b, after Giebel (*Odontographie*, Taf. XVII, Fig. 10, *a*).

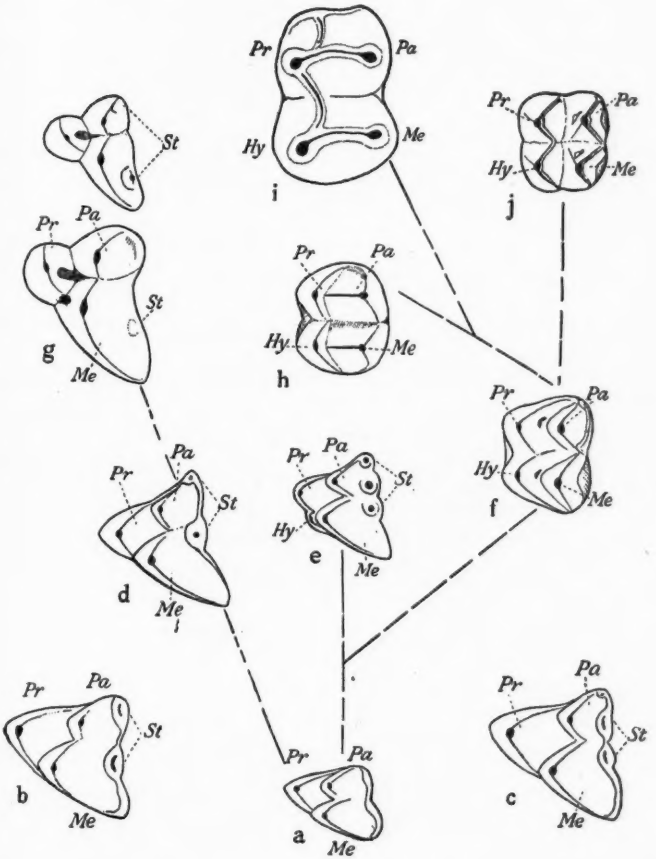


PLATE I.

EXPLANATION OF PLATE II.

Illustrating the patterns of the lower molar teeth in marsupials. (Same references as in Plate I.)

Abbreviations.

Pr^d. — protoconid.	En^d. — entoconid.
Pa^d. — paraconid.	Hy^d. — hypoconid.
Me^d. — metaconid.	Hl^d. — hypoconulid.

a.s. — antero-external shelf.

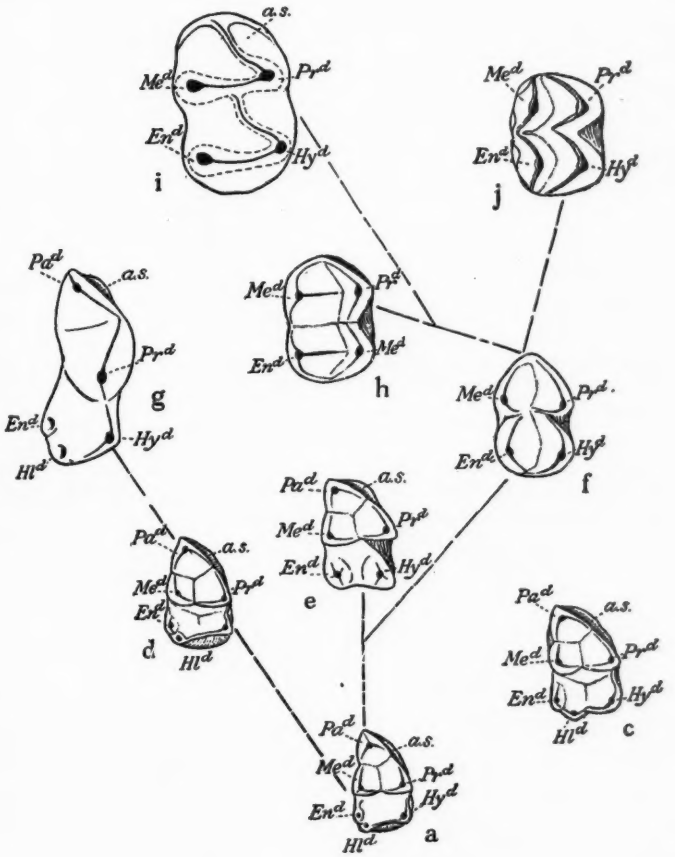

a.s.
Me^d
Pr^d
En^d
Hy^d
i
Me^d
Pr^d
En^d
Hy^d
j
Pa^d
a.s.
Pr^d
En^d
Hy^d
Hl^d
g
Me^d
Pr^d
En^d
Me^d
h
Me^d
Pr^d
En^d
Hy^d
f
Pa^d
a.s.
Me^d
Pr^d
En^d
Hy^d
e
Pa^d
a.s.
Me^d
Pr^d
En^d
Hl^d
d
Pa^d
a.s.
Me^d
Pr^d
En^d
Hy^d
Hl^d
c
Pa^d
a.s.
Me^d
Pr^d
Hy^d
En^d
Hl^d
a

PLATE II.

EXPLANATION OF PLATE III.

Illustrating the modifications of the pes in Marsupials and their probable phylogenetic relations.

a. — *Didelphys nudicaudata* Geoff.
b. — *Phalanger celebensis* Gray.
c. — *Tarsipes rostratus* Gerv. & Verr.
d. — *Sminthopsis murina* Waterh.
e. — *Antechinomys laniger* Gould.
f. — *Phascolomys latifrons* Owen.
g. — *Perameles doreyana* Quoy & Gaim.
h. — *Peragale leucura* Thos.
i. — *Hypsiprymnodon moschatus* Rams.
j. — *Macropus sp.*

Figs. a–i after Dollo.

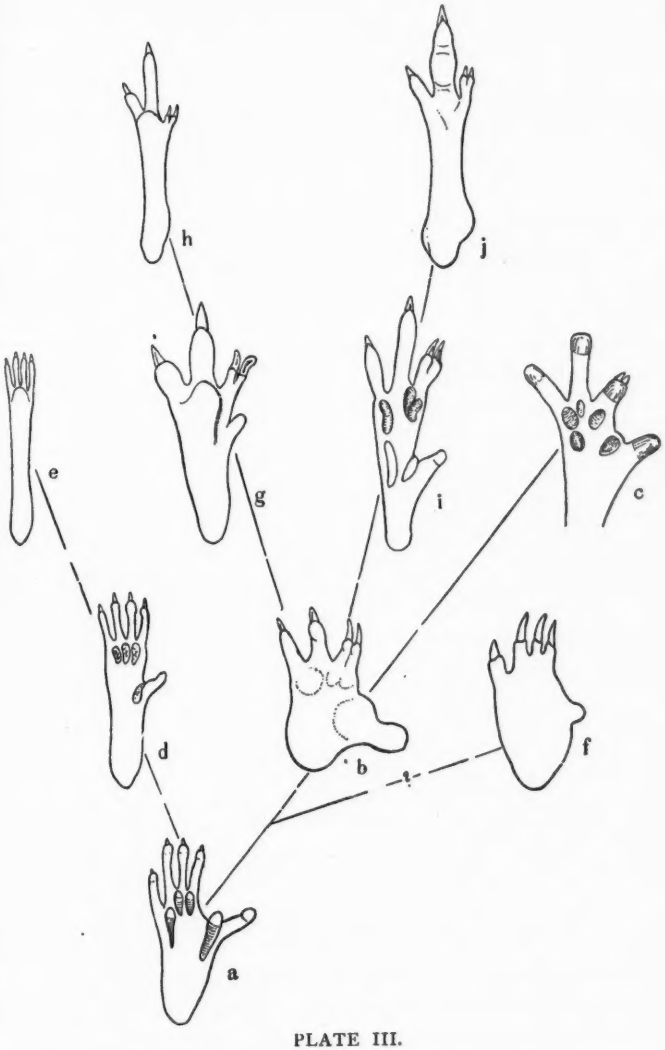


PLATE III.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 121.

A QUANTITATIVE STUDY OF VARIATION IN THE SMALLER NORTH-AMERICAN SHRIKES.

R. M. STRONG.

CONTENTS.

	PAGE.
I. Introduction	271
II. Material	273
III. Methods	274
A. General Precautions	274
B. Measurements of Variable Characters	275
1. Linear Measurements	275
2. Curvature of Bill	275
3. Color Measurements	278
C. Geographical Areas	280
IV. Results	281
A. Indices of Variability	281
1. Wing and Tail	281
2. Length and Depth of Bill	285
3. Color	286
B. Tables of Constants of Frequency Polygons	287
C. Discussion of Results and Conclusions	295
V. Summary	297
Bibliography	298

I. INTRODUCTION.

THE work described in this paper was begun in the fall of 1898, and was carried on at Harvard University during the year 1898–99 under the direction of Dr. Charles B. Davenport. It was completed during the winter of 1899–1900.

It was my desire to employ statistical methods in the study of variation in a group of birds, and to apply the "Precise

Criterion of Species" of Davenport ('98) to a problem in bird classification. The smaller American shrikes of the genus Lanius appeared to me to offer favorable material for the application of quantitative methods to the solution of an interesting taxonomic problem.

The shrikes are a group of passerine birds more or less generally distributed in northern Europe and North America, and probably of circumboreal origin. The large northern shrike, *Lanius borealis* Vieill., of North America grades into the great gray shrike, *L. excubitor* Linn., of Europe; and it exhibits a strong tendency towards individual variation.

In the United States, Mexico, and southern Canada the breeding[1] shrikes are not essentially different from the northern shrike, *L. borealis*, in certain of its color phases, except for smaller size and the more or less complete disappearance of a conspicuous barring or mottling of the breast in adults. This barring of the breast is persistent in most adults of *L. borealis* and characteristic of the juvenile plumage of the southern shrikes, a fact of much phylogenetic interest.

According to the nomenclature of the American Ornithologists' Union there are at present recognized three races or subspecies of the southern or smaller shrikes, which are as follows: *Lanius ludovicianus ludovicianus* Linn., *L. ludovicianus excubitorides* Swains., and *L. ludovicianus gambelli* Ridgw. Subspecies *gambelli* includes the shrikes of California and vicinity. The shrikes of the rest of the country are classed as either ludovicianus or excubitorides, the former being typical in the south central states and the latter in the vicinity of Colorado.

The shrikes of New England and the north central states have been variously classed, by different systematists, as either ludovicianus or excubitorides. Palmer ('98) has proposed for the shrikes of this intermediate region a new subspecies, migrans, whose validity, I believe, can be well tested by the "Precise Criterion" method.

[1] In this paper the breeding range only is considered in discussing geographical distribution.

We have in the shrikes the following eight important variable characters:

1. Length of tail.
2. Length of wing.
3. Length of bill.
4. Depth of bill.
5. Curvature of culmen.
6. Color of dorsal surface of head and back.
7. Color of upper tail coverts.
8. Color of breast.

II. Material.

While the shrikes make good subjects for a study of variation, there has been an unfortunate difficulty in obtaining material in amounts as large as is desirable. Shrikes are not especially common birds in the regions most collected in, and they are considered rare in most parts of New England. They are certainly not abundantly represented in collections of birds, and many of the skins that were obtained were imperfect, or did not come from the breeding areas of the birds.

I have been able to procure measurements of two hundred and ninety-four available skins, obtained from the following sources:

Mr. William Brewster, Cambridge, Mass.	174 skins.
National Museum, Washington, D. C.	64 "
Museum of Comparative Zoölogy	18 "
Mr. J. H. Gaut, Washington, D. C.	15 "
Mr. C. F. Batchelder, Cambridge, Mass.	8 "
Dr. A. K. Fisher, Washington, D. C.	5 "
Mr. N. Hollister, Delavan, Wis.	4 "
Oberlin College Museum, Oberlin, Ohio	4 "
Carnegie Museum, Pittsburg, Pa.	1 "
Mr. William Palmer, Washington, D. C.	1 "

The numbers given do not include skins which, for various reasons, could not be used. I wish here to express my thanks to the gentlemen who have secured for me the loan of the above-mentioned material, and especially to Mr. William Brewster for many courtesies received.

GEOGRAPHICAL DISTRIBUTION.

	MALE.	FEMALE.		MALE.	FEMALE.
Arizona	16	13	Montana	4	3
British Columbia	1	0	Nevada	2	0
California	15	21	New Mexico	0	1
Colorado	1	2	New York	5	2
Connecticut	1	0	North Carolina	3	0
District of Columbia	6	2	North Dakota	1	0
Florida	45	23	Ohio	3	1
Georgia	8	6	Ontario	0	1
Illinois	10	3	Pennsylvania	1	1
Indiana	1	0	South Carolina	16	2
Indian Territory	0	1	Tennessee	1	1
Kentucky	1	0	Texas	7	5
Maine	0	1	Utah	0	1
Massachusetts	1	2	Virginia	4	10
Mexico	17	16	Wisconsin	0	1
Minnesota	1	0	Wyoming	3	1
			Total	174	120

III. METHODS.

A. General Precautions.

It is hardly necessary to say that work of this kind should be done with material in normal condition. I have made no measurements where mutilations existed, and only adult birds bearing good evidence of representing their breeding ranges have been used. It has been necessary to reject a number of skins because of lack of data as to sex. As male and female shrikes are essentially alike in color and differ little in size, it is not possible to verify the original determinations of sex; however, there has been no noticeable confusion in this respect.

No attention has been given to the subspecific distinctions appearing on the labels of skins, for I have considered it important to avoid all possibility of bias of opinion which attention to previous classification might give.

B. Measurements of Variable Characters.

1. *Linear Measurements. Length of Wing.* — The shortest distance between the wrist and the tip of the wing was measured with a pair of dividers, the wing being folded naturally at the side of the body. The left wing was taken in every case for the measurement.

Length of Tail. — This measurement was made from the papilla of the uropygial gland to the extreme end of the tail feathers. One arm of the dividers was placed with its point resting on the anterior face of the papilla. On account of mutilation and frequent difficulty in finding the papilla, the measurement has often to be omitted. Great precision cannot be obtained, as there is irregularity in the relative position of the papilla in the drying of the skin, and there is also usually some wearing away of the distal ends of the rectrices. When the latter were much frayed no measurement was attempted.

Length of Bill. — The only satisfactory method found for measuring the length of the bill was to take the shortest distance between the nostril and the distal apex of the upper mandible. The point of one arm of the dividers was placed against the most distal face of the nostril. I have had to make allowance in some cases for the wearing away of the distal apex of the upper mandible, though the amount of wear is too small to materially affect the measurement.

Depth of Bill. — The greatest dorso-ventral diameter of the bill near its base was determined. There is considerable liability to error here on account of lack of uniformity in the articulation of the mandibles in the dried skin, and I found it necessary to reject quite a number of skins on this account.

2. *Curvature of Bill.* — This is a character of the distal half of the culmen. Its quantitative expression is a matter of some difficulty, for we have here a curve which is not the arc of a circle nor a parabola, nor does it correspond to any geometrical figure. Then, too, the form and size of the bill are such as to render it impracticable to make precise measurements directly. To meet the latter difficulty it was decided to try to trace on paper the enlarged projection of the outline of the bill. After

some experimentation, the following apparatus was devised. Fig. 1 is a diagram of an enlarging camera with a box in front of the lens, at the left in the figure. A circular aperture for the passage of light was made in one side of the box, the oppo-

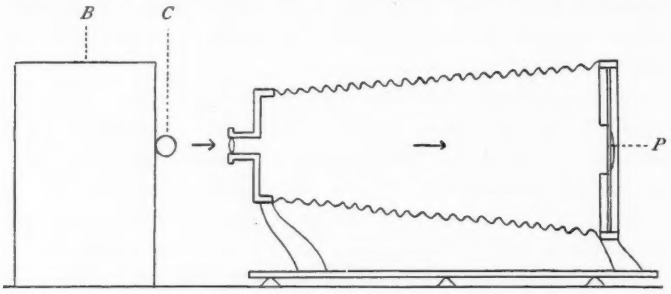


FIG. 1. — Longitudinal section of enlarging camera apparatus. *B*, box; *C*, paper cylinder; *P*, photographic paper in holder.

site side being removed. At one side of the aperture (*A*, Fig. 2) a simple cylinder (*C*, Figs. 1 and 2) of stiff paper just large enough to admit a shrike skin was fastened to the outside of the box in a nearly horizontal position by a single tack.

Orientation was then secured for any skin by the following simple adjustments: (1) rotation of the skin in the cylinder around its longitudinal axis; (2) rotation of the cylinder on the axis formed by the tack; (3) moving the skin in the cylinder towards or away from the aperture; (4) rotation of the box on a vertical axis.

The apparatus was arranged so that the bill of a shrike was about seven inches from the front of the lens and its median plane at right angles to the axis of the camera. Strong diffused daylight was then allowed to pass through the aperture of the box past the bill, and into the lens of the camera, as shown by the arrows in Fig. 1. In the plate-holder at the back of the camera was placed a piece of "velox" paper (a rapid printing photographic paper) about 2×3 inches

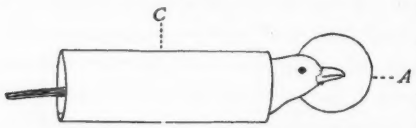


FIG. 2. — Paper cylinder (*C*) holding bird so that the bill projects before aperture (*A*).

in size. An exposure of seventy-five seconds was ordinarily sufficient to obtain a picture, which appeared on development as a white area on a black ground. A magnification of 3⅓ diameters was secured, care always being taken to have the distance of the bill from the lens constant. An outline of the culmen of practicable working size having been thus obtained, the next step was the analysis of the curve.

It was highly desirable to have one simple criterion of the curvature, if one sufficiently representative could be found. In Fig. 3, which represents the outline in a representative case, a great increase in the sharpness of the curvature is seen

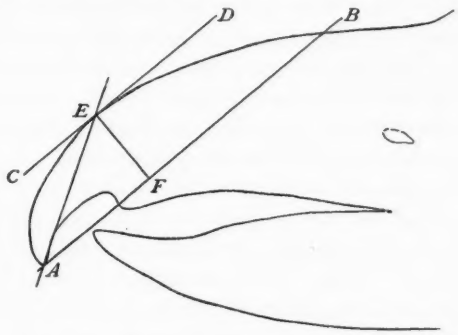


FIG. 3. — Diagram of bill showing method of measuring curvature of culmen. *AB* equals distance of *A* from nearest margin of nostril; *CD*, tangent to outline of culmen parallel to *AB*; *EF*, perpendicular at point of tangency, *E*; *EAF*, angle embraced between the two chords of the culmen, *AB* and *AE*.

towards the distal end of the culmen; the sharpness of curvature varies in different individuals. The point where the rapid increase begins was found on inspection to be sufficiently uniform in position to suggest the idea of comparing in different individuals the angle embraced between two chords of the curve of the culmen, each of them terminating at the distal end of the culmen. The proximal ends of the two chords were selected by the following method: one was established at a point on the culmen as far from its apex as the apex was from the nearest margin of the nostril. The distance of the nostril from the tip of the culmen, of course, could not be measured on the photographic silhouette print; it was therefore determined

by measuring the actual distance in the specimen and multiplying that value by the linear magnification of the print. The nostril distance was used because the nostril was found to be the only point sufficiently definite and constant for the proximal limit. This chord (*AB*, Fig. 3) served as a base line. A line (*CD*) parallel to the base line and tangent to the culmen was next drawn, and at the point of tangency (*E*) a perpendicular (*EF*) was erected between the lines. It was then a simple matter to measure the lines *AF* and *EF*, and with a table of natural tangents to determine the angle *EAF*. This is the angle that has been adopted as a criterion of curvature in the shrike bill. It is easily seen that there might be an infinite number of small variations in the outline of the culmen, especially in the part distal to the point *E*, which would not affect the angle *EAF*; but I believe that a correlation is to be expected between the curvatures in various portions of the culmen, so that it is probable that any considerable variation in outline elsewhere would affect the curvature in the region of *E* and thus find expression in the angle *EAF*. In order, however, to have something more than a subjective impression on this matter, I made a second series of measurements with half the length of the line *AB* used as a chord. The result of these measurements, and their deviations from those of the first set, are given on page 294.

3. *Color Measurements.*—For the quantitative determination of color, the "color mixer" was suggested. A simple form of color mixer — the Bradley Milton Color-Top — was employed. This instrument has a graduated disk, with superimposed paper disks of five different colors, which can be so adjusted as to make compound disks exposing two or more colors. On being rotated at high speed these colors are mixed into one, which is a combination of the colors used in the proportions of the number of degrees of each exposed. With the aid of this apparatus it is therefore possible to determine the proportions of these primary colors entering into any color effect which may be produced by various combinations of them. To determine the composition of any color in nature, it is necessary to reproduce empirically that color in the top and note the

combinations that have given the desired effect. In practice, however, the following conditions were found essential to accurate estimation of color: (1) Uniform strong diffused daylight, preferably coming from a skylight or north window and not subject to strong reflections from colored surfaces; (2) frequent comparison with previously made estimates; (3) careful comparison of the color obtained by the top with that of the plumage, whose color is being measured, both being viewed from different directions.

I found it impracticable to make color estimates for more than two hours continuously, because of color fatigue of the eye.

In spite of the above precautions, there are limitations to the use of the color-top. In the estimation of color, the personal equation plays an important part. Then, too, the surface of the color disks is very different in character from that of feathers. The peculiar luster or sheen so characteristic of a bird's plumage cannot be imitated by the color mixer. In estimating the color of the breast, more or less mottling, which exists in some cases, increased the difficulty. In such cases I have attempted to estimate the mean color. Some apparatus for blending a complex pattern into one color would be very desirable. I do not attempt to maintain that estimates of the same material by another person would exactly agree with mine; but I believe that I have a consistent classification of individuals according to color.

After several weeks of experimentation I found that, though there were traces of blue, red, and yellow, the colors black and white were by far the most important elements in the areas measured. Therefore I have taken as the color criterion the amount of black, or the melanism, of the color area described; and color estimates appear in the tables as percentages of melanism. I have found it more difficult to estimate colors containing more than 50% of white than those in which black predominated, and I have not attempted to make fine distinctions as to melanism in the lighter color areas. The large amount of black necessary to produce even the lightest grays in the color mixer was a matter of surprise to me. To

properly appreciate the estimates of color given in this paper, a color mixer should be used to reproduce the combinations given.

Ability in the discrimination of color I have found to be much developed by experience. The color determinations of my first three months' work were rejected, as increased power of discrimination made more accurate results possible.

C. Geographical Areas.

The material described in this paper has been collected from a territory of great size and varying conditions, and it is therefore desirable to compare individuals both as parts of a single group and in subdivisions corresponding to natural life areas, so that correlations between individual variability and geographical variation may be made. I have adopted the life areas employed by Allen ('93) for the territory covered by my material, which are four in number:

1. *Austroriparian Subprovince*, embracing North and South Carolina, Georgia, and Florida.

2. *Appalachian Subprovince*, embracing Maine, Massachusetts, Connecticut, District of Columbia, Virginia, Ontario, New York, Pennsylvania, Indiana, Kentucky, Ohio, Illinois, Wisconsin, Minnesota, and North Dakota.

3. *Campestrian Subprovince*, embracing British Columbia, Montana, Wyoming, Colorado, Indian Territory, New Mexico, Texas, Idaho, Utah, Arizona, and Nevada.

4. *Sonoran Subprovince*, embracing California, Lower California, and Mexico.

A comparison of variations for still smaller areas is desirable, but this, to be useful, would require more material than I have been able to obtain. The subspecies of shrikes have the distribution given by Palmer ('98), excepting gambelli (Palmer did not consider the western shrikes), which agrees very well with the above life areas. The inhabitants of each are:

SUBPROVINCE.	SUBSPECIES.
Austroriparian	= ludovicianus
Appalachian	= migrans
Campestrian	= excubitorides
[Sonoran	= gambelli]?

IV. Results.

A. Indices of Variability.

1. *Wing and Tail.* — In Figs. 4–8, frequency polygons based on measurements of various dimensions, the position of the mean class is indicated by a heavy vertical line. In Fig. 4 are given frequency polygons for the lengths of the wing (4 *A*) and tail (4 *B*) of all available male shrikes. They show a striking absence of variability for these characters in a series of individuals representing four subprovinces with greatly varying conditions.

In Tables I–III are given correlations between the length of wing and the length of tail. I have used the method of Duncker (Davenport, '99, p. 33) in determining coefficients of correlation. The "probable error" has also been determined by the following formula (Davenport, '99, p. 34), in which ρ is the coefficient of correlation.

$$\text{P. E. } \rho = \frac{0.6745\,(1-\rho^2)}{\sqrt{n}\,(1+\rho)}$$

On comparing Tables II and III, we find that Florida shrikes have a greater length of tail in relation to the length of wing than shrikes from the Appalachian subprovince.

The correlation in these characters for the series from the Appalachian subprovince is seen to be 0.157− greater than that of the Florida series. This difference is possibly due in part to the skewness of the curves of frequency for these series, which renders precise correlations difficult.

Table I. — 140 Male Shrikes from the Entire Region.

Mean of wing = 99.06 + mm. Mean of tail = 101.571 + mm.
σ_1 = 2.74 + mm. σ_2 = 3.48 + mm.

	Wing, Subject.					Tail, Relative.					
X_2	−7	−5	−3	−1		0	2	4	6	8	
Rel. class	94	96	98	100		102	104	106	108	110	mm.
Sub. class (I)											(II)
X_1											
94 mm.	−5			4	3	1					
96 mm.	−3	2	2	6	8	3		1			
98 mm.	−1	1	3	9	11	11	6	4			
100 mm.	0		1	5	9	6	7	6	2		
102 mm.	2			2	1	6	3	2			
104 mm.	4					1		5	3	3	
106 mm. (III)	6						2		1		(IV.)

$\rho = 0.5688 +$ P. E. $\rho = \pm 0.038 +$

TABLE II. — 41 MALE SHRIKES FROM FLORIDA.

Mean of wing = 97.463 + mm. Mean of tail = 102.292 + mm.
σ_1 = 2.29 + mm. σ_2 = 3.14 + mm.

	WING, SUBJECT.				TAIL, RELATIVE.				
X_2	− 6	− 4	− 2	0	1	3	5	7	
Rel. class	96	98	100	102	104	106	108	110	mm.
Sub. class (I)									(II)
X_1									
94 mm. − 3		4	3	1					
96 mm. − 1	1		5	1					
98 mm. 0		1	1	7	4	3			
100 mm. 2				2	2	3	2		
102 mm. 4									
104 mm. (III) 6								1	(IV)

$\rho = 0.639 +$ P. E. $\rho = \pm 0.0487$

TABLE III. — 28 MALE SHRIKES FROM THE APPALACHIAN SUBPROVINCE.

Mean of wing = 99.357 + mm. Mean of tail = 99.43 + mm.
σ_1 = 2.31 + mm. σ_2 = 3.063 + mm.

	WING, SUBJECT.			TAIL, RELATIVE.				
X_2	− 5	− 3	− 1	0	2	4	6	
Rel. class	94	96	98	100	102	104	106	mm.
Sub. class (I)								(II)
X_1								
96 mm. − 3	2		1	1				
98 mm. − 1	1	1	5	4				
100 mm. 0			2	4				
102 mm. 2			1		2	1	1	
104 mm. 4							1	
106 mm. (III) 6						1		(IV)

$\rho = 0.796 +$ P. E. $\rho = \pm 0.0348 +$

A general tendency towards great length of tail in southern birds has been noted by Allen (**'71**, pp. 230, 231). In Table VII, p. 291, the mode of lengths of tail for Austroriparian males is seen to be 102 mm.; whereas Appalachian males have a mode of 100 mm. The mean of Austroriparian shrikes is 101.91 + mm., while that of Appalachian shrikes is 99.43 + mm.,

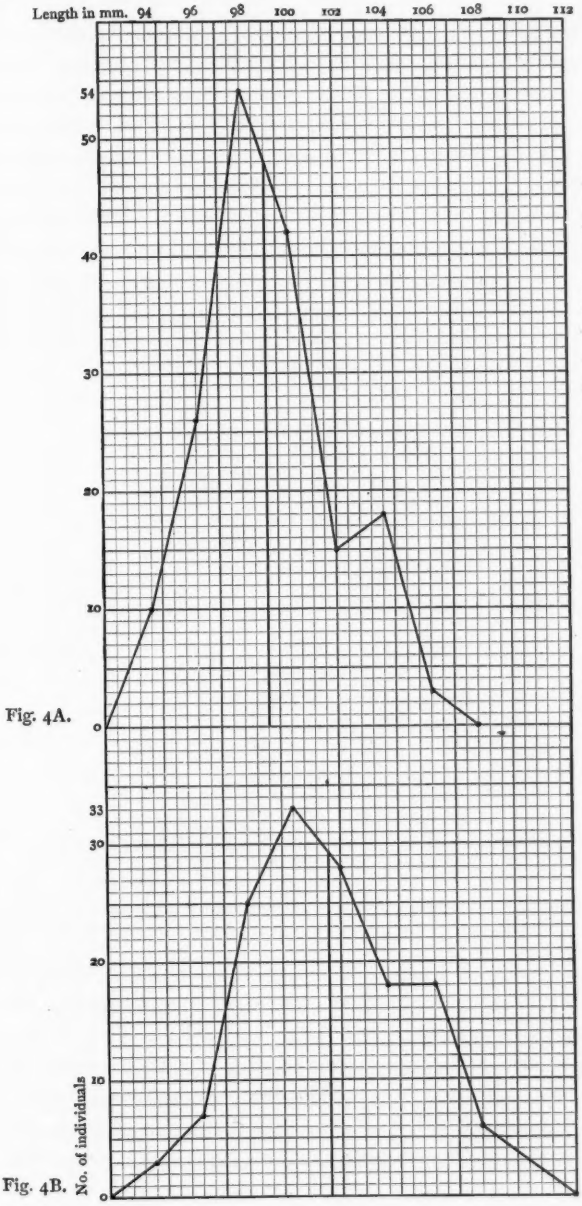


FIG. 4. — Frequency polygons. *A*, Classes of left wings for 168 males from entire region; *B*, tails of 141 males from entire region.

a difference of 2.48 mm. Austroriparian females show a still greater preponderance in length of tail, having a mode 6 mm. greater and a mean 3.05 mm. greater. Not much importance, however, can be attached to the great difference of the modes in this case, because of the small number of females measured.

Palmer ('98) says, in referring to shrikes of the Appalachian and Austroriparian subprovinces respectively: "In migrans

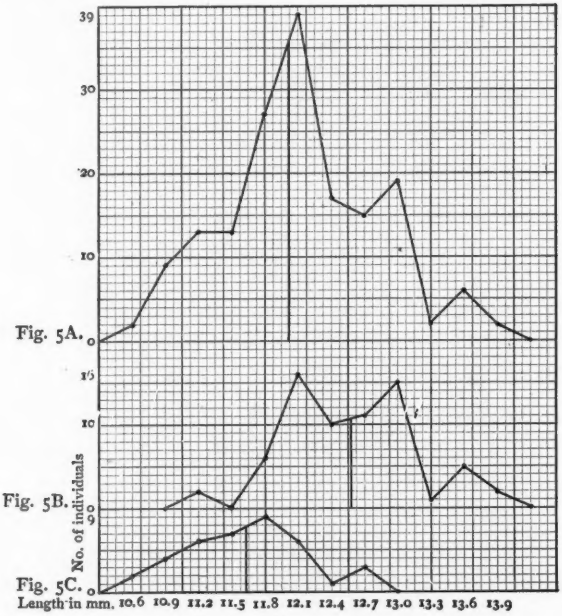


FIG. 5. — Frequency polygons for length of bill. *A*, 164 males from entire region; *B*, 69 males from Austroriparian subprovince; *C*, 38 males from Appalachian subprovince.

[Appalachian] the wing is longer than the tail, due to its migratory habit; in ludovicianus [Austroriparian] the tail is longest, thus indicating its fixed habitat."

I find, on the contrary, that the wing is not absolutely longer than the tail in the Appalachian form, though from Tables VI and VII, pp. 290, 291, it is clear that the excess of the length of tail over that of the wing is less in migrans than in ludovicianus;

or, in other words, that *relatively to the tail*, the wing is longer in migrans than in ludovicianus, as his theory would require.

Palmer's explanation of length of wing in migrans as the result of habit is plausible. However, it has not been proved that shrikes which migrate northward actually fly any more than those remaining in Florida; moreover, it seems to me that there are other possible explanations. I am inclined to think that we have here a case of the condition already noted

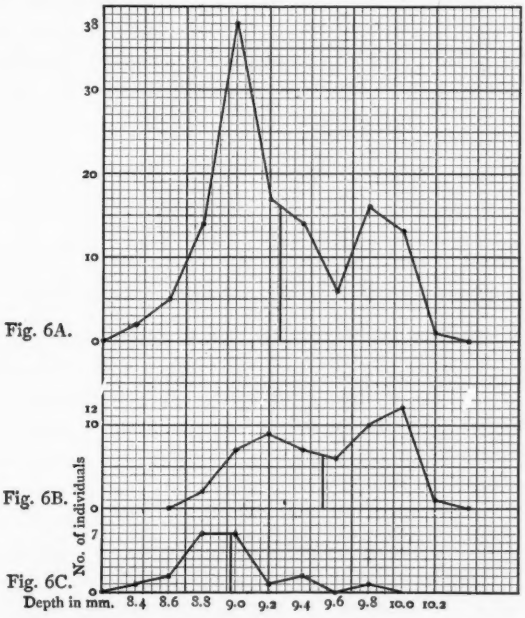


FIG. 6. — Frequency polygons for depth of bill. *A*, 126 males from entire region; *B*, 54 males from Austroriparian subprovince; *C*, 21 males from Appalachian subprovince.

by Allen — a tendency towards greater length of tail in tropical birds. Unfortunately I cannot prove this, — any more than Palmer does his hypothesis, — for it has not been possible to determine the actual ratios of tail length and wing length with reference to the general size of the bird.

2. *Length and Depth of Bill.* — In Fig. 5 are given frequency polygons of variations in length of bill for the entire region and

for two subprovinces. Here is shown a considerable separation of the means (indicated by the vertical line) for the subprovince polygons, indicating a larger bill for Austroriparian shrikes (5*B*), which are also seen in Fig. 6*B* to have a greater depth of bill. The increase in size found in the bills of Florida shrikes is also shown by comparison of Tables IV and V, in which these characters are correlated for a series of Florida[1] shrikes and a series from the Appalachian subprovince. A striking absence of correlation and a great tendency towards individual variation in the proportions of the bill are to be seen. Increase in the relative size of the bill in many southern birds has been noted by Allen ('71). It would be an interesting field for statistical investigation.

TABLE IV. — 32 MALE SHRIKES FROM FLORIDA.

Classes of Depth of Bill.	Classes of Length of Bill in Millimeters.										Total.
	11.2	11.5	11.8	12.1	12.4	12.7	13.0	13.3	13.6	13.9	
8.8 mm. . .				1	1						2
9.0 mm. . .				1			1				2
9.2 mm. . .				2		1			1	1	5
9.4 mm. . .			1				1		1		3
9.6 mm. . .					2						2
9.8 mm. . .			1	1		1	1		2		6
10.0 mm. . .			1	5	1		4				11
10.2 mm. . .						1					1
Total . . .			3	10	4	3	7		4	1	32

3. *Color.* — Frequency polygons for variations in the melanism of the head are shown in Fig. 7. The upper polygon (Fig. 7*A*), which includes the entire series, is seen to be distinctly bimodal, and in the lower polygons we see that the mode of greater melanism is due to the presence of Austroriparian shrikes, and that the shrikes of the Campestrian subprovince have the least melanism for the dorsal surface of the head.

[1] Only Florida representatives of the Austroriparian shrikes were taken in this case, in order to eliminate intermediate forms, for it seemed desirable to me to compare the Appalachian shrikes with a group as nearly tropical as possible.

The Campestrian subprovince includes arid portions of the United States, where paleness of color in the fauna is supposed to be correlated with this condition.

TABLE V. — 22 MALE SHRIKES FROM THE APPALACHIAN SUBPROVINCE.

Classes of Depth of Bill.	Classes of Length of Bill in Millimeters.									Total.
	10.6	10.9	11.2	11.5	11.8	12.1	12.4	12.7	13.	
8.4 mm.			1							1
8.6 mm.	1								1	2
8.8 mm.			1	3		1				5
9.0 mm.	1	1	2	1	1	1		1		8
9.2 mm.			1			1				2
9.4 mm.				1		1	1			3
9.6 mm.										0
9.8 mm.			1							1
Total.	2	1	6	5	1	4	1	1	1	22

While such correlations are frequently suggested by the fauna of desert regions, the relations of humidity to color are still problems for further investigation.

Very great variations in the melanism of the upper tail coverts are shown in Fig. 8. The shrikes of the Campestrian subprovince have here also a mode of little melanism, 30%, while a mode of great melanism, 70%, is found for Austroriparian shrikes. The upper tail coverts of Campestrian shrikes, especially those from Colorado and Arizona, are very light gray. This peculiarity has caused the race to be designated as the white-rumped shrikes.

B. Tables of Constants of Frequency Polygons.

In Tables VI–XIII will be found indices of variation for all the material studied. All computations have been made from measurements grouped into classes. This grouping has been adopted both in drawing the polygons and in determining the indices of variability, in order to reduce the "probable error."

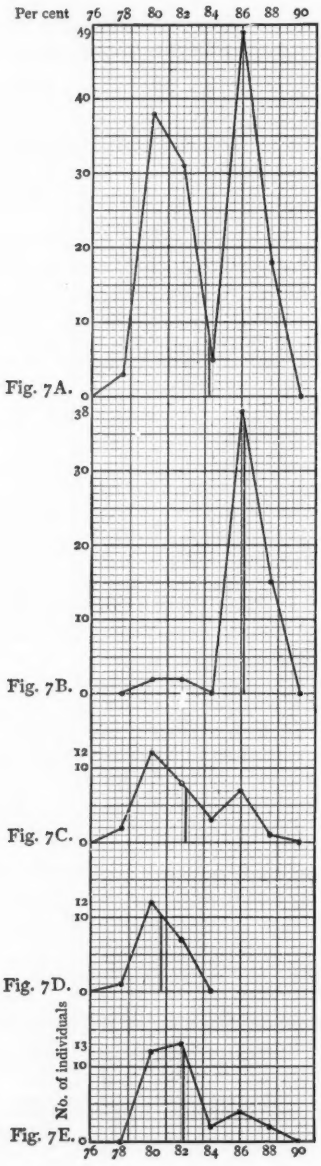


FIG. 7. — Frequency polygons for melanism of top of head. *A*, 144 males from entire region; *B*, 57 males from Austroriparian subprovince; *C*, 33 males from Appalachian subprovince; *D*, 21 males from Campestrian subprovince; *E*, 33 males from Sonoran subprovince.

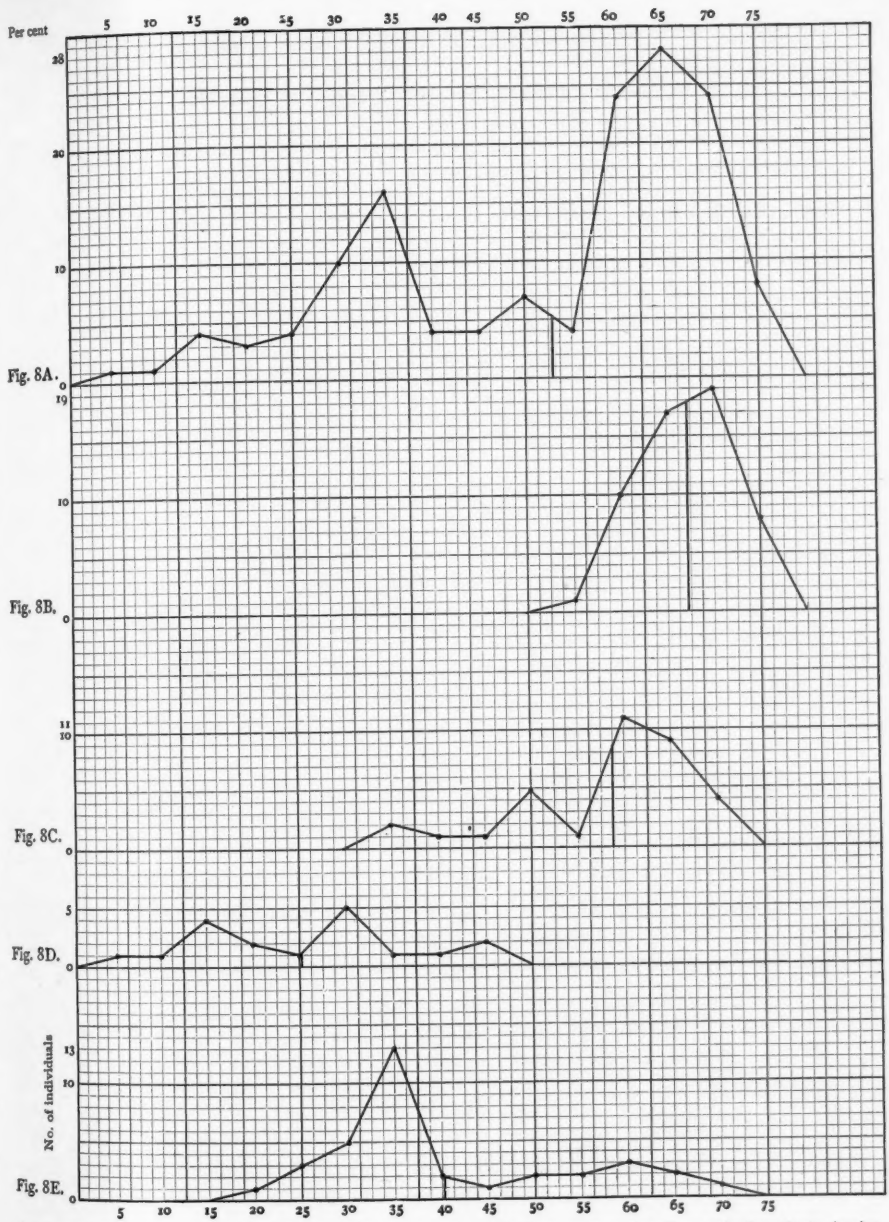


FIG. 8. — Frequency polygons for melanism of upper tail coverts. *A*, 142 males from entire region; *B*, 55 males from Austroriparian subprovince; *C*, 34 males from Appalachian subprovince; *D*, 18 males from Campestrian subprovince; *E*, 35 males from Sonoran subprovince.

The following constants of the frequency polygons have been determined (Davenport, '99) :

1. Mode : Class of greatest frequency.
2. Mean : $M. = \frac{\Sigma (V. f)}{n}$.
3. Standard Deviation, $\sigma = \sqrt{\frac{\Sigma (x.^2 f)}{n}}$.
4. Coefficient of variability : $CV. = \frac{\sigma}{M} \times 100$.
5. Probable error of Mean : $P.\ E.\ M.$ [sub.] $= \pm 0.6745 \frac{\sigma}{\sqrt{n}}$.
6. Probable error of Standard Deviation : $P.E.\sigma$ [sub.] $= \pm 0.6745 \frac{\sigma}{\sqrt{2n}}$.

TABLE VI. — LENGTH OF LEFT WING.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	168 males.		99.09 + mm.	2.79 + mm.
	112 females.		97.98 + mm.	2.64 + mm.
Austroriparian .	70 males.	98 mm.	97.6 + mm.	2.04 + mm.
	31 females.	96 mm.	96.64 + mm.	2.35 + mm.
Appalachian . .	35 males.	98–100 mm.	99.2 mm.	2.45 + mm.
	25 females.	98 mm.	97.68 mm.	2.17 + mm.
Campestrian . .	27 males.	104 mm.	101.26 mm.	2.45 + mm.
	24 females.	102 mm.	99.75 mm.	2.79 + mm.
Sonoran . . .	36 males.	98 mm.	100.28 mm.	2.90 + mm.
	32 females.	98 mm.	98.19 + mm.	2.36 + mm.

CV. of 168 males = 2.81 +. *CV.* of 112 females = 2.69 +.

P. E. M. [sub.] 168 males = ± 0.145.

P. E. σ [sub.] 168 males = ± 0.1026 +.

TABLE VII. — LENGTH OF TAIL.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	141 males.		101.55 + mm.	3.49 + mm.
	95 females.		99.55 + mm.	3.63 + mm.
Austroriparian .	65 males.	102 mm.	101.91 + mm.	3.12 + mm.
	30 females.	104 mm.	100.47 + mm.	3.25 + mm.
Appalachian . .	28 males.	100 mm.	99.43 + mm.	3.06 + mm.
	19 females.	98 mm.	97.42 + mm.	3.85 + mm.
Campestrian . .	20 males.	104 mm.	102.3 mm.	3.48 + mm.
	18 females.	102 mm.	99.89 + mm.	3.42 + mm.
Sonoran . . .	28 males.	100 mm.	102.21 + mm.	3.90 + mm.
	28 females.	102 mm.	99.43 + mm.	3.88 + mm.

CV. of 141 males = 3.43 +. *CV.* of 95 females = 3.65 +.
P. E. M [sub.] 141 males = ± 0.198 +.
P. E. σ [sub.] 141 males = ± 0.14008 +.

TABLE VIII. — LENGTH OF BILL.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	164 males.		12.01 + mm.	0.71 + mm.
	112 females.		11.71 + mm.	0.63 + mm.
Austroriparian .	69 males.	12.1 mm.	12.58 + mm.	0.59 + mm.
	30 females.	12.1 mm.	12.17 + mm.	0.51 + mm.
Appalachian . .	38 males.	11.8 mm.	11.63 + mm.	0.56 + mm.
	29 females.	11.9 mm.	11.26 + mm.	0.54 + mm.
Campestrian . .	25 males.	12.1 mm.	11.84 + mm.	0.63 + mm.
	20 females.	12.1 mm.	11.57 + mm.	0.51 + mm.
Sonoran . . .	32 males.	12.1 mm.	11.96 + mm.	0.54 + mm.
	35 females.	12.1 mm.	11.76 + mm.	0.53 + mm.

CV. of 164 males = 5.89 +. *CV.* of 112 females = 5.35 +.
P. E. M. [sub.] 164 males = ± 0.0374 +.
P. E. σ [sub.] 164 males = ± 0.0264 +.

TABLE IX. — DEPTH OF BILL.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	126 males.		9.27 + mm.	0.42 + mm.
	85 females.		8.95 + mm.	0.41 + mm.
Austroriparian .	54 males.	10.0 mm.	9.54 + mm.	0.38 + mm.
	22 females.	9.2 mm.	9.32 + mm.	0.37 + mm.
Appalachian . .	21 males.	8.8–9.0 mm.	8.95 + mm.	0.30 + mm.
	19 females.	8.8 mm.	8.90 + mm.	0.36 + mm.
Campestrian . .	19 males.	9.0 mm.	9.08 + mm.	0.28 + mm.
	14 females.	8.8 mm.	8.8 + mm.	0.30 + mm.
Sonoran . . .	32 males.	9.0 mm.	9.12 + mm.	0.44 + mm.
	30 females.	8.8–9.0 mm.	8.78 + mm.	0.36 + mm.

CV. of 126 males = 4.57 +. *CV.* of 85 females = 4.61 +.
P. E. M. [sub.] 126 males = ± 0.0252 +.
P. E. σ [sub.] 126 males = ± 0.0178 +.

TABLE X. — MELANISM OF TOP OF HEAD.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	144 males.		83.57 + %.	3.00 + %.
	99 females.		83.66 + %.	3.19 + %.
Austroriparian .	57 males.	86%.	86.17 + %.	1.69 + %.
	24 females.	88%.	87.25 + %.	1.81 + %.
Appalachian . .	33 males.	80%.	82.24 + %.	2.68 + %.
	25 females.	80%.	82.32 + %.	3.03 + %.
Campestrian . .	21 males.	80%.	80.67 + %.	1.13 + %.
	17 females.	80%.	80.94 + %.	1.78 + %.
Sonoran . . .	33 males.	82%.	82.24 + %.	2.4 + %.
	33 females.	82%.	83.45 + %.	2.38 + %.

CV. of 144 males = 3.58 +. *CV.* of 99 females = 3.81 +.
P. E. M. [sub.] 144 males = ± 0.1686.
P. E. σ [sub.] 144 males = ± 0.119 +.

TABLE XI. — MELANISM OF UPPER TAIL COVERTS.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	142 males.		53.13 + %.	15.42 + %.
	104 females.		47.98 + %.	18.99 + %.
Austroriparian .	55 males.	70%.	67.22 + %.	5.02 + %.
	25 females.	65%.	66.2 %.	8.16 + %.
Appalachian . .	34 males.	60%.	58.38 + %.	9.3 + %.
	20 females.	60%.	53.2 %.	6.4 + %.
Campestrian . .	18 males.	30%.	25.28 + %.	11.4 + %.
	17 females.		28.25 + %.	14.8 + %.
Sonoran . . .	35 males.	35%.	40.43 + %.	13.01 + %.
	43 females.	30%.	38.26 + %.	13.37 + %.

CV. of 142 males = 29.02 +. *CV.* of 104 females = 39.58 +.
P. E. M. [sub.] 142 males = ± 0.873 +.
P. E. σ [sub.] 142 males = ± 0.617 +.

TABLE XII. — MELANISM OF BREAST.

AREA.	MATERIAL.	MODE.	MEAN.	STANDARD DEV.
Entire region .	124 males.		31.21 + %.	11.07 + %.
	98 females.		36.58 + %.	10.51 + %.
Austroriparian .	42 males.	25%.	23.81 + %.	6.66 + %.
	27 females.	35%.	32.41 + %.	10.36 + %.
Appalachian . .	35 males.	35%.	43.28 + %.	9.4 %.
	23 females.	40%.	47.61 + %.	8.71 + %.
Campestrian . .	17 males.	25%.	27.65 + %.	7.27 + %.
	18 females.	35%.	31.39 + %.	6.63 + %.
Sonoran . . .	30 males.	25%.	29.5 %.	6.65 + %.
	30 females.	35%.	35.0 %.	7.30 + %.

CV. of 124 males = 35.48 +. *CV.* of 98 females = 28.72 +.
P. E. M. [sub.] 124 males = ± 0.6709 +.
P. E. σ [sub.] 124 males = ± 0.474 +.

Because of limited time I was unable to obtain measurements of culmen curvature for more than forty-seven individuals (partly males and partly females), a number so small that a rather large probable error is found for coefficients of variability.

The results obtained are given in the following table.

TABLE XIII. — CURVATURE OF CULMEN.

	23°	24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	36°	MEAN.
Austroriparian	1					1	1	1	2						28.66° +
Appalachian .				3	2	2	4	5	2	3	1				29.32° +
Campestrian .					2	4	1	1	1	0	2	2	2	1	31.00°
Sonoran . .								1	1				1		32.00°
Total	1			3	4	7	6	8	6	3	3	2	3	1	29.936°

Austroriparian	$\sigma = 2.74° +.$	$CV. = 9.58 +.$	$P.E.\ \sigma = \pm 0.534 +.$
Appalachian	$\sigma = 2.03° +.$	$CV. = 6.92 +.$	$P.E.\ \sigma = \pm 0.206 +.$
Campestrian	$\sigma = 3.12° +.$	$CV. = 10.06 +.$	$P.E.\ \sigma = \pm 0.372 +.$
Sonoran	$\sigma = 2.16° +.$	$CV. = 6.75.$	$P.E.\ \sigma = \pm 0.594 +.$
Total	$\sigma = 2.74° +.$	$CV. = 9.15 -.$	$P.E.\ \sigma = \pm 0.191 +.$

The shrikes of the Austroriparian subprovince, mostly Florida birds, are seen to have a mean curvature $3.34° -$ less than that of the Sonoran birds measured. With so few individuals precise statements as to curvature are not very reliable, but I believe that the figures given are approximately correct for the four subprovinces represented. The series of measurements of the curvature of the culmen when half the base line *A B* (Fig. 3) was used as the chord gave the following constants and coefficients of variability for the forty-seven individuals measured in the first series: Mean, $26.34° +$; Mode, $27°$; $\sigma = 2.33° +$; $CV. = 8.85$; $P.E.\ \sigma = \pm 0.162 +$.

The angles obtained from the second series of measurements were never greater than those from the first series. The greatest deviation from the first set of measurements was $7°$, which occurred in four cases. All the deviations are indicated in the following table:

0°	1°	2°	3°	4°	5°	6°	7°	
4	2	6	10	10	7	4	4	individuals.

It was impossible to get as accurate results in the second series, because of greater difficulty in determining the actual point of tangency, but the results obtained show that there is a fairly close correlation in the curvature for various parts of the bill; that is, where the culmen is much curved in one place, it is likely to have correspondingly strong curvature at other points.

The only selection exercised in the whole work was employed in the estimation of curvature, individuals which appeared on inspection to be typical for their respective subprovinces having been chosen, since it was impossible, for want of time, to photograph the entire series.

C. Discussion of Results and Conclusions.

Although computations have been carried out to the third or fourth decimal place, figures beyond the second decimal place are not given, as they would imply a degree of precision which is not attainable in an investigation of this kind. For example, the mean length of wing for 168 male shrikes is seen to be (see Table VI) 99.09 + mm. It often happened in making correlations that, because of general wear or some special mutilation to a single character, some individuals could not be included in a correlation table. This has happened especially often in the case of the tail, so that in the correlation table for wings and tails only 140 of the 168 male shrikes could be included. The mean for the left wings of the series of 140 shrikes was found to be 99.06 mm. (see Table I), a result which differs from the mean of the whole lot (168) by 3 in the second decimal place.

The modes and means given for the melanism of the breasts of Appalachian-subprovince shrikes show a percentage which, though higher than in other subprovinces, is not as high as would have been the case had not a large proportion of individuals come from localities intermediate between the Campestrian and Appalachian subprovinces. Shrikes from New England were found to have 50–60% of melanism for the breast. An analysis of material shows that only five skins

were obtained from New England, whereas Illinois alone is represented by thirteen. This lack of equalization in the sources of material prevents certain desirable interpretations of tendencies towards minor variations.

To my mind one of the most important results reached is the determination of the relative variability of different characters in a group of birds representing geographical areas of considerable size. The coefficients of variability (Tables VI–VII) indicate for the wing and tail a variability of less than 4 in length. The bill is somewhat more variable, as is shown by a coefficient of 5.89 + for the length of bill in a series of 164 males. Color, as would be expected, is much more subject to variation. The upper tail coverts and breast are the most variable; but the coverts furnish only a very small part of a bird's coloration, and the color of the breast was the character which it was the most difficult to measure satisfactorily, especially as advanced age and the condition of the plumage are factors of possible importance which I have found it difficult to consider. Fortunately for this particular study, shrikes do not change much after the first winter plumage is obtained.

I believe that migrans is as worthy of recognition as gambelli. Whether it is profitable to encumber nomenclature with the names of these races, based on slight variations, is a question which is worthy of further consideration.

The power of discriminating fine shades of color varies in different persons, and it can be highly developed by education. At the present time there is much activity among certain systematists in the production of new subspecies for geographical varieties, which long experience and special adeptness enable them to distinguish. A variation, no matter how slight, that can be correlated with geographical range is considered to warrant an addition to nomenclature; but the discovery and description of geographical races can be carried on almost *ad infinitum*.

Birds, because of their powers of flight, might be expected to be less subject to the factor of isolation than non-migratory animals, but the tendency to return in spring to the same breeding place must, in some species at least, be conducive to

the formation of numerous local variations, or family characteristics, whose recognition is a matter of power of discrimination on the part of the systematist.

It seems highly desirable that the question of limiting the establishment of new subspecies or varieties by some generally accepted criteria be considered.

I do not argue for the universal use of the method of the "Precise Criterion," but I believe that it is both desirable and practicable to employ it in certain problems of taxonomy, such, for instance, as the one just discussed. The ordinary work of classification, perhaps, does not at present require the precision in treatment furnished by purely quantitative methods, but problems of race distinction, I believe, need the precision of the "Precise Criterion." The contention that quantitative methods are less useful than those ordinarily employed because of the large amount of material required, is mischievous, for it argues that generalizations professing precision are possible by methods which are not precise. The problems of finer classification can be properly settled only by the use of a large amount of material, whatever the methods used.

V. Summary.

Quantitative methods have here been applied to the study of variation in the smaller shrikes of North America, and the following variable characters have been measured:

1. Length of wing.
2. Length of tail.
3. Length of bill.
4. Depth of bill.
5. Curvature of culmen.
6. Color of dorsal surface of head.
7. Color of upper tail coverts.
8. Color of breast.

The three color areas have been found to vary principally in the amount of melanism present. A series of 294 shrike skins from various parts of the United States, Mexico, and southern Canada have been studied and measurements of these skins have been classified.

Coefficients of variability have been determined as follows for the whole series.

	Males	Females
Length of wing	2.81 +	2.69 +
Length of tail	3.43 +	3.65 +
Length of bill	5.89 +	5.35 +
Depth of bill	4.57 +	4.61 +
Melanism of top of head	3.58 +	3.81 +
Melanism of upper tail coverts	29.02 +	39.58 +
Melanism of breast	35.48 +	28.72 +
Curvature of culmen	47 males and females 9.15 −	

Florida shrikes were found to have relatively large bills and long tails.

A large percentage of melanism has been found for the top of head and the back of shrikes from the south central states, while shrikes from the vicinity of Colorado and Arizona have a relatively small percentage of melanism for all three color surfaces measured.

I wish to make acknowledgments to Dr. Davenport for supervision of the work and helpful criticisms, and to Dr. Mark for suggestions and revision of the manuscript.

Cambridge, Mass.

BIBLIOGRAPHY.

Allen, J. A.

'71. On the Mammals and Winter Birds of East Florida, with an Examination of certain assumed Specific Characters in Birds, and a Sketch of the Bird Faunae of Eastern North America. *Bull. Mus. Comp. Zoöl.* Vol. ii, No. 3, pp. 161–450.

Allen, J. A.

'93. The Geographical Origin and Distribution of North-American Birds, considered in Relation to Faunal Areas of North America. *The Auk.* Vol. x, No. 2, pp. 97–150, 2 pls.

Davenport, C. B.

'98. A Precise Criterion of Species. *Science* (N.S.). Vol. vii, No. 177, pp. 685–690.

Davenport, C. B.

'99. Statistical Methods with Special Reference to Biological Variation. 59 pp., 10 tables, and 28 figs. New York, John Wiley & Sons.

Palmer, W.

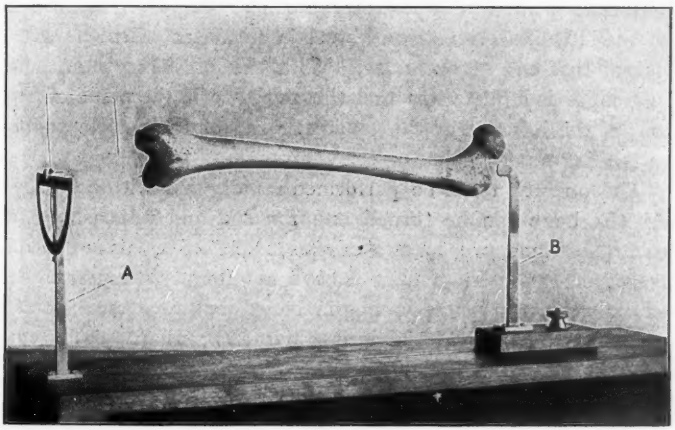
'98. Our Small Eastern Shrikes. *The Auk.* Vol. xv, No. 3, pp. 244–258.

A NEW INSTRUMENT FOR MEASURING TORSION.[1]

FRANK RUSSELL.

THE apparatus that has heretofore been used to measure the torsion of the long bones of the human skeleton has been so difficult of manipulation as to be impracticable. The following description of a simpler apparatus is offered in the hope that it may prove useful to those who are interested in statistical somatology.

The base is 7 by 30 inches; it is grooved for a distance of 14 inches from the middle to within 2 inches of the right end. The post *A*, 8 inches high, is fixed to the base, and has a spur



projecting 3¼ inches toward the right. An ordinary brass protractor is attached to the top of the post at right angles to the spur. (A protractor with the figures reversed in position would be better.) The center of the protractor is fixed at the axis of the spur, on which is pivoted a U-shaped needle that

[1] Demonstrated at the winter meeting of Section H of the American Association for the Advancement of Science, at Baltimore, Dec. 27, 1900.

rises 3½ inches above the spur and extends downward externally to the protractor scale. The right end of the needle should terminate in an eye, through which the spur passes ; the figure represents the trial needle not thus arranged.

The post *B* is movable ; its base slides in the groove of the base board and is held in position by a thumbscrew. The top is provided with a strip of steel 3 inches in length. The strip is provided with saw teeth that engage the head and great trochanter of the femur at the same time (or both condyles), for it is pivoted at its center and stands in the plane of the long axis of the bone. This strip is fixed in an exactly vertical position, and the protractor is exactly horizontal in relation to it.

The torsion of any long bones can be measured with this instrument. The axis of each end is first indicated in pencil; the spur of the post *A* is then engaged with the lower portion of the axial line at one end of the bone; the post *B* is pushed to the left until the strip of steel is in contact with the axial line of that end of the bone. With the left hand the needle on post *A* is adjusted so that the arms are in the plane of the axis of the left end of the bone, the end of the needle points to the degree of torsion on the protractor.

The operation can be performed rapidly and with accuracy. As the bone can be turned end for end and remeasured in other positions, we have a ready means of making control measurements. In practice I have not found it necessary to use any support for even fragile bones, but to insure against accident to such material it is advisable, perhaps, to have a narrow table between the posts of the apparatus, which will not support the bone but simply prevent its falling far enough to injure it.

The apparatus can be made by any skilled mechanic. The model figured here was made for me by a graduate student of anthropology, Mr. W. C. Farabee, at Harvard University.

PEABODY MUSEUM OF
AMERICAN ARCHÆOLOGY AND ETHNOLOGY.

SYNOPSES OF NORTH-AMERICAN INVERTEBRATES.

XIV. The Hydromedusæ — Part I.

CHARLES W. HARGITT.

Introductory.

The following synopsis was undertaken more than a year ago as a section of the "Synopses of North-American Invertebrates" now in course of publication. Various interruptions have delayed its completion at an earlier date.

While compiled largely from the author's notes and observations made upon the Hydrozoa of the Atlantic coast during a period of more than ten years, the form and method of presentation are patterned after the systematic works of Hincks, Allman, Haeckel, and von Lendenfeld. For many of the descriptive notes recourse has been had to L. Agassiz's *Contributions to the Natural History of the United States* and to A. Agassiz's *Catalog of the Acalephæ of North America*, as well as to those of the authors just named.

The synopsis is confessedly incomplete in several of the orders, specially upon the Campanularidæ and Leptomedusæ. It is, moreover, limited to a comparatively small range of hydrozoan life of American waters, chiefly of the northeastern Atlantic coast. Of that of the Pacific coast our present knowledge is still too limited to warrant even a provisional synopsis.

The Hydromedusæ comprise one of the three generally recognized classes of Cœlentera, of which the others are the Scyphomedusæ and Anthozoa. While the first two classes have been regarded as much more intimately related phylogenetically than has the third, it may be doubted whether after all their relation may not be quite remote, at least so much so as to warrant separate consideration. Hence slight, if any, reference

will be made to the Scyphomedusæ in considering possible relationships or phylogeny among the Hydromedusæ.

The Hydromedusæ may be distinguished by the following somewhat broad characteristics. In typical cases there is a more or less well marked alternation of generations, *i.e.*, a non-sexual, hydroid stage and a sexual, medusoid, stage. The latter are derived by a process of budding from the stem or hydranth of the hydroid as gonophores which may become free as medusæ or may exhibit varying phases of degeneration as medusoids or mere sporosacs, as in Clava, Campanularia, etc.

In many cases there may be exhibited proliferous medusæ from various portions of the parent medusa, as in Hybocodon. In rare cases one or other of these phases may be entirely lacking, as in Hydra, in which the medusa phase is wholly absent, or as in Rhegmatodes and many others the hydroid stage is apparently lacking.

Perhaps in no phylum of the animal world is there a more striking exhibition of polymorphism than among the Hydromedusæ. This seems to reach its climax in the Siphonophora, though in such forms as Hydractinia it is also evident.

In general the hydroid exhibits a sedentary habit quite in contrast with the free-swimming habit of the medusa. But here again are numerous exceptions. Hydra is capable of locomotion, as are also other hydroid forms, while as already indicated many medusæ are sessile and degenerate, and in the Siphonophora the entire polymorphic colony is free-swimming. In general the hydroids are colonial though with notable exceptions, as in Hydra and many others. While in general form the hydroid and medusoid present rather striking morphological differences, they may yet be reduced to a common and fundamental likeness. Both are of diploblastic structure, having a definite ectoblast and entoblast separated by a middle lamella, or mesoglœa, which is a delicate, structureless membrane in the hydroid and in the medusa a rather massive, gelatinous structure, making up the bulk of the body and giving it the characteristic glassy appearance.

In the absence of definite knowledge concerning details of the life history of many of the Hydromedusæ, it is as yet

impossible to formulate any scheme of classification which shall bring into a single view the complete ontogenetic relations of the various hydroid and medusoid phases. In the present synopsis I have followed in the main that of Allman and Hincks for the hydroids and that of Haeckel for the medusæ, though in each there is not a little variation both as to the order of presentation as well as the nomenclature used.[1]

SYNOPSIS OF ORDERS OF HYDROMEDUSÆ.

I. Hydrariæ.

Polyps solitary, never forming colonies; no medusoids; sex-cells produced in ectoderm of polyps.

Of this order only a single well-defined genus is recognized, Hydra. The genera Protohydra and Microhydra are probably allied genera, but their affinities are too uncertain as yet to warrant definite classification. The former is of marine habit, the latter of fresh-water habit. Both are devoid of tentacles, and sexual reproduction, at least in the former, seems unknown.

Of the genus Hydra there are two well-distinguished species: *H. fusca* and *H. viridis*. Both abound in fresh waters of small lakes, ponds, and sluggish streams, associated with various aquatic plants, notably Lemna, various algæ, pond lilies, etc.

II. Hydrocorallinæ.

Colonial. Hydrosome comprising polyps of two forms, gastrozoids and dactylozoids, supported from a network of cœnosarcal hydrorhizæ, from the ectoderm of which is secreted a calcareous mass which is deposited over the spaces or meshes of the network. The colonies form incrusting, often arborescent, masses over shells, stems of Alcyonaria, or other support, often forming massive and fantastic shapes, as in the so-called "stag's horn coral." Only one genus is likely to come within the range of the present synopsis, namely, Millepora; and of this a single species, alcicornis.

III. Tubulariæ (Gymnoblastea).

The Tubulariæ are for the most part colonial hydroids, producing free medusæ, or medusoid gonophores, by budding. Hydroids devoid of

[1] Just as these notes were being put into final form for the press, I have been permitted to consult the manuscript of a forthcoming *Handbook of the Hydroida of the Woods Hole Region*, by Professor C. C. Nutting, for the privilege of which I am under grateful obligations.

hydrothecæ and gonangia. Sexual individuals when set free are known as Anthomedusæ. Medusæ ocellate, *i.e.*, the sensory bodies, are visual in character, and are located usually at the bases of the tentacles. Gonads borne in the tissues of the manubrium.

IV. CAMPANULARIÆ (Calyptoblastea).

Hydroids with hydrothecæ and gonangia. Colonial; propagating by budding both in development of hydrosome and in formation of gonosomes, the latter of which may become free as medusæ, or only partially develop as medusoids, with only rudimentary medusan organs. Medusæ with sensory organs of the vesiculate type, otocysts, borne upon the margin of the bell, usually between bases of tentacles. Gonads borne under the radial canals. Medusæ when free are Leptomedusæ.

V. TRACHOMEDUSÆ.

Hydromedusæ devoid of hydrosome (hypogenic), medusa developing directly from the egg; no alternation of generations known. Sensory organs chiefly tentaculocysts, containing endodermal otoliths. Gonads borne under radial canals. Medusæ generally somewhat hemispherical in shape, with thick mesoglœa. Radial canals, four, six, or eight, often centripetal.

VI. NARCOMEDUSÆ.

Hydromedusæ devoid of hydrosome (hypogenic), development of medusa being direct with no alternation of generations. Medusa rather flat in shape, and with radial canals in form of broad gastric pouches, which vary in number, as do also the tentacles, which are usually set at some distance up on the outer surface of the umbrella.

VII. SIPHONOPHORA.

Hydromedusæ with free-swimming, polymorphic colonies, produced by differential budding. The colonies of this order are characterized by an extreme specialization of the several types of individuals which comprise them. Reproductive products borne in gonophores which seldom become free.

KEY TO FAMILIES OF TUBULARIÆ.

Hydranth devoid of specialized receptacles, hydrothecæ. Sexual products not borne in closed gonangia.

1. Hydranths with scattered, filiform tentacles . . . . CLAVIDÆ, 1
2. Hydranths with single whorl of filiform tentacles:
   a. Hypostome conical, not abruptly differentiated.
      b. Colony regularly branched . . . . . BOUGAINVILLIDÆ, 3

b'. Colony not branched. Hydrorhiza of anastomosing canals, forming an incrusting base, overlaid with ectodermal cœnosarc.

c. Hydranths with sessile, fixed gonophores . HYDRACTINIDÆ, 5

c'. Hydranths producing free medusæ . . . PODOCORYNIDÆ, 6

a'. Hypostome trumpet-shaped or hemispherical . . EUDENDRIDÆ, 4

3. Hydranths with more than a single whorl of filiform tentacles:

a. Stem provided with definite sheath of horny perisarc.

b. Distal tentacles in two whorls . . . . . HYBOCODONIDÆ, 10

b'. Distal tentacles not in two whorls . . . . . TUBULARIDÆ, 9

a'. Stem not provided with definite sheath of perisarc, more or less definitely marked with longitudinal flutings or cœnosarcal channels CORYMORPHIDÆ, 8

4. Hydranths with scattered, somewhat spirally disposed, capitate tentacles only . . . . . CORYNIDÆ, 2

5. Hydranths with proximal circle of filiform tentacles, and with distal capitate tentacles on hypostome . . . . . PENNARIDÆ, 7

1. CLAVIDÆ.

Colonial, stems simple or branching, hydranths elongate, clavate, with numerous filiform tentacles irregularly disposed over the body. Gonophores borne upon hydranth, or on special branches, or occasionally arising from the hydrorhiza. Medusoids never free.

GENERA.

1. CLAVA. Colony of simple, unbranched individuals, devoid of perisarc, except near the base.

2. RHIZOGETON. Colony very similar to Clava. Gonophores arising from hydrorhiza.

3. CORDYLOPHORA. Colony profusely branched and with definite sheath of perisarc.

Clava leptostyla Ag.

Trophosome: Hydranths simple, with slender basal portion which arises from a filiform hydrorhiza protected by a delicate perisarcal covering, which extends slightly upon the bases of the polyps. Tentacles numerous, filiform, and scattered over the hydranth.

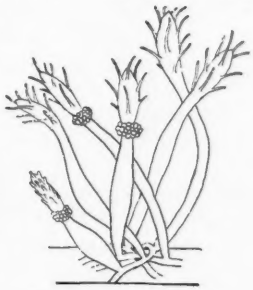


FIG. 1.— *Clava leptostyla* Ag. (Adapted from Allman.)

Gonosome: Gonophores in clusters at base of tentacles, medusoids never becoming free. Male gonads of a bright pinkish hue, similar, in general, to that of the colony. Female gonads of a rather distinctly purple color.

Habitat: Shallower waters on fucus, docks, sea wall, etc., at Cold Spring Harbor, Woods Holl, Hadley Harbor, etc.

Rhizogeton fusiformis Ag.

(*Contr. Nat. Hist. U. S.*, vol. iv.)

Trophosome: Colony much as in Clava. Hydranths of about ¼ inch in height, tentacles about twelve in number, borne on distal half of polyp.

Gonosome: Gonophores oval, arising from hydrorhiza on short peduncles, the whole invested by filmy perisarc.

Habitat: Rocky pools between tide marks, Massachusetts Bay.

Cordylophora lacustris Allman.

Trophosome: Colonial, profusely branching, hydranths with scattered filiform tentacles.

Gonosome: Gonophores borne on branches, ovate and with definite investment of perisarc.

Habitat: Brackish, and fresh waters in lagoons, ponds, etc.

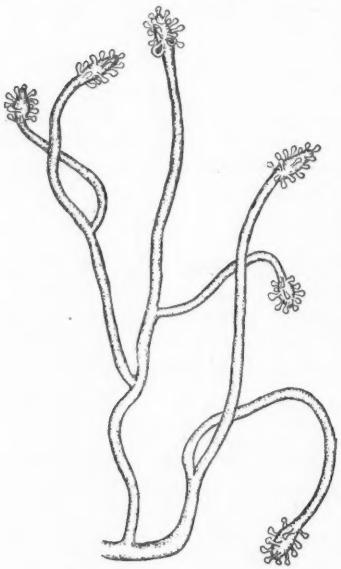


FIG. 2.—*Syncoryne mirabilis* Ag. (After Agassiz.)

2. CORYNIDÆ.

Colonial, hydranths with capitate tentacles only, scattered over the elongated bodies, or growing in indefinite whorls. Gonophores usually borne among the proximal tentacles, or from body of polyp and producing medusæ, which may become free or remain attached.

GENERA.

1. SYNCORYNE. Stem invested by definite perisarc; hydranths claviform.

2. CORYNITIS. Stem devoid of definite perisarc; hydranths sessile, with long, cylindrical bodies.

Syncoryne mirabilis Ag.

Trophosome: Branched, perisarc smooth or with only slight indication of annulations. Hydranths with numerous capitate tentacles.

Gonosome: Medusæ borne on hydranth body. These are of two forms, one free and developing earlier, hemispherical, with well-developed tentacles, with an ocellus at their base; the other fixed, tentacles rudimentary, and devoid of ocelli.

Corynitis agassizii McCr.

Trophosome: Colonial, not branched, hydranths with cylindrical, highly contractile bodies, and spirally arranged, capitate tentacles.

Gonosome: Gonophores growing low on body of hydranth or among the proximal tentacles. Medusæ almost spherical, the surface dotted with clusters of nematocysts. Marginal tentacles two or four, nodulated and swollen with batteries of nematocysts.

Habitat: Shells of Mytilis, usually overgrown with incrustations of Membranopora.

3. BOUGAINVILLIDÆ.

Colonial, branching, with distinct perisarc. Hydranths with conical hypostome and a single whorl of filiform tentacles. Gonophores borne just below the hydranth. Medusæ with four radial canals, marginal tentacles either single or in clusters, and with ocelli at their bases.

GENERA.

1. BOUGAINVILLIA. Hydrocaulus with dense perisarc. Medusæ with clustered marginal tentacles and with branching oral tentacles.

2. PERIGONIMUS. Stems with gelatinous perisarc. Medusæ with two marginal tentacles and without oral tentacles.

FIG. 3. — *Bougainvillia superciliaris* Ag. (After Agassiz.)

Bougainvillia superciliaris Ag.

Trophosome: Colony attaining a height of about two inches. Stem irregularly branched, branches annulated proximally. Hydranths with inconspicuous hypostome and from fifteen to twenty tentacles.

Gonosome: Gonophores borne mostly on pedicels from ultimate branches. Mature medusæ with heavy manubrium and branched tentacles, those of margin arising from conspicuous sensory bulbs. Colony light color with greenish tinge, hydranth light rose tint. Medusæ with yellowish manubrium tipped with red, sensory bulbs reddish orange.

Bougainvillia (Margelis) carolinensis McCr.

Trophosome: Colony sometimes eight to twelve inches high, usually much smaller. Stem profusely branching, with hydranths freely distributed on both stem and branches, and of elongate and flexible, subconical form. Tentacles about twelve.

Gonosome: Gonads borne on both stem and branches, often in clusters.

Medusæ much as in previous species, but with narrower and shorter hypostome. Colony light grayish tinged with dull green, hydranths with reddish tint. Medusæ with brick-red manubrium and sensory bulbs, ocelli black.

Habitat: Piles of docks, occasionally on seaweed and floating timbers.

Perigonimus.

Colonial, rarely attaining a height of more than ½ of an inch, simple or branched, perisarc usually gelatinous and extending to base of tentacles. Hydranths relatively large and with conical hypostome. Medusæ borne on hydranths or on stem or branches, bell-shaped and with two to four tentacles with bulbous bases.

Perigonimus jonesii.

(*American Naturalist*, vol. xxviii, p. 27.)

Trophosome: Colonial, branching freely, with thick, gelatinous perisarc, often wrinkled, extending to, or even including, the bases of tentacles. Hydranths with subconical hypostome, with about sixteen filiform tentacles, alternately elevated and depressed.

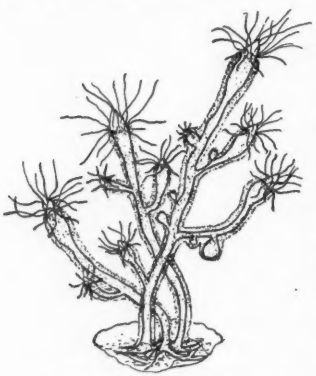


FIG. 4.—*Perigonimus jonesii.*

Gonosome: Medusæ ovoid or hemispherical, with four radial canals and ocelli, but having only two tentacles, which are often spirally coiled and disposed within the subumbrellar cavity.

Habitat: Found only upon the abdomen and legs of the spider crab, *Labinia marginata*, Cold Spring Harbor, L. I.

4. EUDENDRIDÆ.

Colonial, often branching with great profusion, becoming quite arborescent. Perisarc distinct, more or less annulated, attached by creeping hydrorhiza. Hydranths flask-shaped, with sharply differentiated, trumpet-shaped hypostome. Tentacles filiform, forming a single whorl about the base of the hydranth. Male gonophores borne in a verticil just beneath the tentacles of hydranth, which in some species become directly metamorphosed into gonophores. Female gonophores not verticillate, usually borne on body of hydranth, which often becomes transformed into gonophores with their peculiar spadiceous, finger-like coils enclosing the ova. The family includes a single genus, Eudendrium, fairly characterized in the accompanying cut. The following species are designated:

Eudendrium ramosum Linn.

Trophosome: Colony arborescent, much branched, attaining a height of from four to six inches. Branches rather symmetrical, pinnate and somewhat alternate, with similar sub-branches. Hydranths somewhat ovoid, with trumpet-shaped hypostome, and with single verticil of about twenty tentacles, some of which are often atrophied in male.

Gonosome: Sexes distinct, though often growing in approximate colonies. Gonophores of female somewhat pyriform and scattered, springing from body of hydranth or occasionally directly from stem. Male gonophores spring from base of hydranth close beneath the tentacles in moniliform clusters, each from three to four chambered. Color of male reddish, of female orange. Abundant on piles of docks, on racks, etc., in shallower waters.

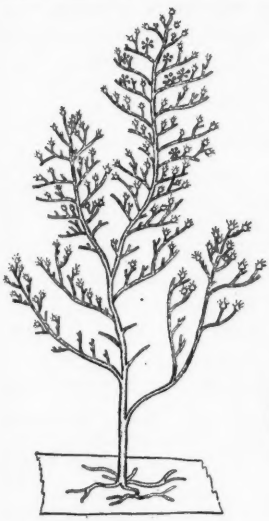


FIG. 5.

FIG. 6.

Eudendrium ramosum Linn.
(After Allman.)

FIG. 5. — Colony.
FIG. 6. — Hydranth with gonophores.

Eudendrium dispar Ag.

(*Cont. Nat. Hist. U. S.*, vol. iv.)

Trophosome: Colony large, from three to five inches in height, stems more slender than in former, somewhat fascicled, extensively and variously branched and annulated. Hydranths vasiform, with about twenty-eight tentacles.

Gonosome: Sexes distinct. Gonophores of female of pinkish orange hue, variously clustered about the base of the more or less atrophied hydranth and from distal portion of stem. Habitat in deeper waters in Vineyard Sound, attached to rocks, shells, etc.

Eudendrium tenue A. Ag.

(*No. Am. Acalephæ*, p. 160.)

Trophosome: Colony very small, rarely exceeding an inch in height, branching irregularly, hydranths vasiform, borne on slender pedicels.

Gonosome: Male gonophores from two to four chambered, of pinkish color, clustered from bases of tentacles. Female gonophores bright orange in color, scattered over the branches and stem. Habitat on seaweed, etc., in shallower waters. Not abundant.

Eudendrium capillare Alder.

Of the distinctness of this species and *E. album*, listed by Professor Nutting, I have grave doubts. It seems to me that Alder's diagnosis of capillare coincides so closely with that of *E. tenue* as to render their identity highly probable. So also of *E. album*. Specimens taken at Woods Holl seem almost certainly identical with *E. tenue*, and therefore both should probably be merged under *E. capillare*, whatever slight differences there are being hardly greater than varied environment would easily explain.

5. HYDRACTINIDÆ.

The Hydractinidæ are so closely allied to the following family that it seems unfortunate that they were not originally merged; the only easily distinguishable difference being in the free medusæ of the latter in contrast with the fixed sporosacs of the former. In size, general habit, and morphology they are so closely identical that but for the gonosomes no difference would be recognizable, though in Podocoryne the hydrorhiza seems less definitely covered with naked cœnosarc, — but even this differs greatly i specimens from different localities.

In both polymorphism is a marked feature, at least three types of polyps being distinguishable:

1. Feeding hydranths (trophopolyps), whitish in color and with numerous filiform tentacles, frequently appearing in alternately elevated and depressed order.

2. Reproductive individuals (gonopolyps), more slender-bearing gonophores in clusters below the tentacles, which are fewer in number than in the first and imperfectly developed.

3. Spiral polyps, elongated individuals, wholly devoid of tentacles and with apex of body thickly beset with nematocysts.

The entire colony arises from an incrusting base which is thickly beset with jagged spines, the latter sometimes considered a fourth type of individual.

FIG. 7. — *Hydractinia echinata*. (Adapted from Hincks.)

Hydractinia echinata Fleming.

(Hydractinia polyclina Ag., *Cont. Nat. Hist. U. S.*)

Trophosome: Colony composed of numerous polyps, as given above.

Gonosome: Gonads as sessile sporosacs borne on distinct hydranths, gonopolyps, having but few tentacles. Medusoids never free.

Habitat: Usually found upon shells occupied by the hermit crab, but occasionally found upon fucus and occasionally also upon piles of docks.

6. Podocorynidæ.

Colony very similar to that of the Hydractinidæ, as given above. Hydranths with single whorl of filiform tentacles surrounding base of the conical hypostome.

Podocoryne carnea Sars.

Trophosome: Hydranths slender, pinkish-white in color, and with filiform tentacles.

Gonosome: Medusæ borne in clusters about the hydranth just below the whorl of tentacles. When set free the medusa is of marked bell-shape, with definite velum, short manubrium of reddish color, four radial canals from the bases of which arise eight marginal tentacles.

Habitat as in Hydractinia.

Stylactis.

Under this generic name Sigerfoos describes (*American Naturalist*, Vol. XXXIII) a hydroid having many points in common with the Podocorynidæ, and it should probably be classed under this family. He has given to it the specific name Hooperi (*cf. op. cit.*). The following definitive characters have been given of it:

Trophosome: Hydranths slender, with a length when fully expanded of about ¼ of an inch. Tentacles in single whorl, filiform, and of variable number, eighteen to twenty-five.

Gonosome: Gonophores borne upon specialized hydranths just below tentacles, and set free as medusæ having four radial canals, eight tentacles which are somewhat rudimentary, devoid of ocelli. Sexual products borne upon manubrium. Found on shells of *Stygnassa* (Illyanassa) *obsoleta*.

7. Pennaridæ.

Colony arborescent, pinnately branched, hydranths with two sets of tentacles, one proximal composed of ten to twelve, filiform, the other borne upon hypostome in two indefinite whorls, short and capitate.

Pennaria tiarella McCrady.

Trophosome: Colony attaining a height of from five to six inches, usually smaller in colonies attached to eelgrass or seaweed. Regularly branching, stem somewhat undulating, or geniculate in young colonies, regularly annulated just above branches, as are also the latter at point of origin. Hydranths large and flask-shaped, those terminating stem or branches appreciably larger than others.

Gonosome: Medusæ borne on hydranth body above the whorl of proximal tentacles. Medusæ liberated during early evening and discharging the sex products immediately thereafter. In many cases the ova are discharged before the liberation of the medusæ, as indeed are also the sperms.

Habitat: Abundant on piles of docks, floating timber, eelgrass, fucus, etc., usually in shallower waters. Development from June to October.

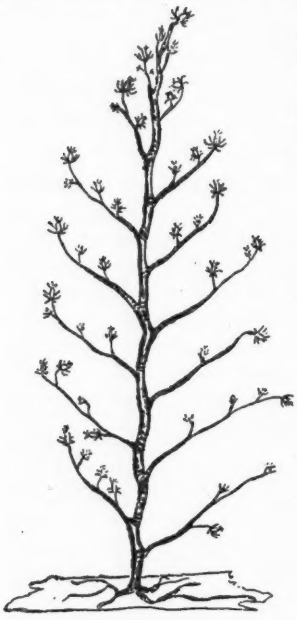


FIG. 8.

8. CORYMORPHIDÆ.

Usually solitary, though I have occasionally found definite colonial

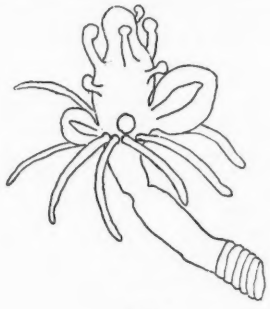


FIG. 9.

FIG. 8. — *Pennaria tiarella* McCr.
FIG. 9. — Hydranth enlarged, showing origin of medusæ.

buds arising direct from the hydrorhiza. Hydranths with proximal and distal whorls of filiform tentacles. Gonophores as free medusæ with four radial canals and with one to four marginal tentacles, one of which is usually much the larger.

Corymorpha pendula Ag.

(*Cont. Nat. Hist. U. S.*, vol. iv.)

Trophosome: Hydrocaulus from two to four inches in height, the fleshy cœnosarc traversed by longitudinal canals which ramify more or less near the base. Hydrorhiza an indefinite root-like expansion of the base, by which the whole is attached to the sandy substratum.

Hydranths flask-shaped, sharply distinct from stem. Proximal tentacles large, forming a single whorl at base of hydranth. Distal tentacles very contractile, forming alternating verticils about the base of the hypostome.

Gonosome: Medusæ borne on branched peduncles, arising just above the proximal tentacles, ovoid hemispherical, with single large and usually three rudimentary tentacles.

Hydroid bright pink in color, medusæ light yellowish, manubrium, tentacles, and bulbs pinkish.

Habitat: Sandy bottom in rather deep waters at various points in Vineyard Sound, Muskegat Channel, etc.

FIG. 10. — *Corymorpha pendula* Ag. (Modified from Allman.)

9. TUBULARIDÆ.

Hydrocaulus with definite perisarc, simple or irregularly branched. Hydranths flask-shaped, with proximal and distal whorls of filiform tentacles. Gonophores in form of fixed sporosacs, borne on branched peduncles.

Tubularia.

Generic description as given for family. The following species are given:

Tubularia couthouyi Ag.

(*Cont. Nat. Hist. U. S.*, vol. iv.)

Trophosome: Stems unbranched, attaining a height of from four to six inches. Hydranths large, often expanding an inch or more in diameter, with proximal whorl of thirty to forty filiform tentacles and a distal one of much smaller.

Gonosome: Gonophores as numerous, densely crowded racemes of pendulous sporosacs. Larvæ escaping as actinulæ. Hydranth and gonads bright pinkish red.

Habitat: On sandy bottoms dredged off Nobska Point, Vineyard Sound, and other similar places in the same locality.

Tubularia larynx Ellis and Solander.

Trophosome: Stems clustered, more or less branched, annulated. Height one to two inches. Stem forming a collar-like expansion just below hydranth, the latter bearing sixteen to twenty proximal filiform tentacles and a distal whorl of about the same number.

Gonosome: Gonads in pendulous clusters, similar to last. Color of hydranth and gonads rosy. Perisarc yellowish.

Tubularia spectabilis Ag.

(*Thamnocnidia spectabilis* Ag., *Cont. Nat. Hist. U. S.*)

Trophosome: Colony irregularly branched and sparsely annulated. Height three to four inches. Hydranths much as in former.

Gonosome: Comparable with former.

Tubularia tenella Ag.

(*Thamnocnidia tenella* Ag.)

Trophosome: Colony very small, rarely exceeding a height of one and one-half inches. Stem loosely branched and with indefinite annulations. Hydranths with tentacles about as in former.

Gonosome: Compare *T. larynx*. Color and habitat much as in last.

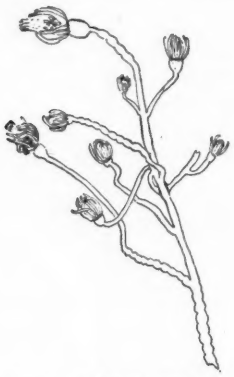


FIG. 11. — *Tubularia tenella* Ag.

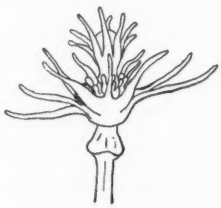


FIG. 12. — Single hydranth enlarged. (After Agassiz.)

FIG. 13. — *Tubularia crocea* Ag.

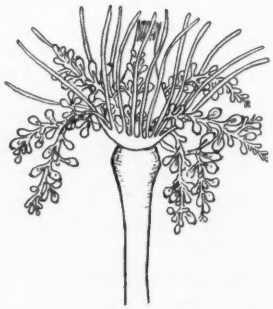


FIG. 14. — Hydranth with pendulous gonophores.

Tubularia crocea Ag.

(Parypha crocea Ag.)

Trophosome: Colonies growing in dense tufts of tangled stems of from three to four inches in height. Stems sparingly branched, with occasional indications of annulations. Hydranths with tentacles much as in former species, but numbering from twenty to twenty-four in each whorl.

Gonosome: Much as in the first species. Hydranths and gonads of rosy-red color, stem pale, whitish. Habitat. Growing in dense masses on piles of docks, floating timbers in harbors, and shallower waters.

Hypolitis perigrinus Murbach.

Under this name Murbach describes a hydroid taken at Woods Holl (*Quar. Journ. Mic. Sci.*, Vol. XLII), which would seem to have some affinities with the Tubularidæ. The following characters are summarized:

Trophosome: Colony consisting of simple hydranths with long hypostome and with distal and proximal whorls of filiform tentacles. Polyp free.

Gonosome: Gonads borne on hypostome just above proximal tentacles and occur singly in the type specimen. Sessile medusoids, somewhat terete in form and devoid of tentacular processes.

FIG. 15. — *Hybocodon prolifer* Ag. (After Agassiz.)

10. HYBOCODONIDÆ.

Hydrocaulus unbranched, solitary, with definite perisarc and hydrorhiza. Hydranths large, with proximal and two distal whorls of filiform tentacles.

Hybocodon prolifer Ag.

(*Cont. Nat. Hist. U. S.*, vol. iv.)

Trophosome: Stems longitudinally striated, occasioned by cœnosarcal canals. Perisarc enlarged and annulated just below hydranth. Hydranth similar to those of the Tubularidæ, but with oral tentacles in two distinct whorls.

Gonosome: Gonophores closely attached to hydranth body just above proximal tentacles. Free medusæ with four radial canals, and with a single greatly enlarged tentacle from whose base a number of secondary medusæ successively bud, and from these still other groups of similar medusæ may arise.

SYRACUSE UNIVERSITY.

REVIEWS OF RECENT LITERATURE.

ZÖOLOGY.

Jordan and Snyder on Japanese Fishes. — In the *Proceedings of the United States National Museum* (XIII, 335), Jordan and Snyder give a list of the fishes collected in Japan by Professor Keinosuke Otaki in 1895 and 1896, and by the "Albatross" in 1896, these collections being in the Museum of Stanford University and the United States National Museum. Fourteen species are described as new and most of them figured by Mrs. Starks. These are *Chimæra phantasma*, *Gobio biwæ*, *Gobio mayedæ*, *Otakia rasborina*, *Congrellus meeki*, *Pseudotolithus mitsukurii*, *Sebastodes hakodatis*, *Sebastodes scythropus*, *Scorpæna onaria*, *Callionymus beniteguri*, *Trifissus ioturus*, *Blennius yatabei*, *Cœlorhynchus kishinouyei*, and *Verasper otakii*. The species last named is probably not distinct from *Verasper grigorjewi*, lately described as a species of Hippoglossus from Hakodate by Herzenstein. The manuscript name of *Lampetra mitsukurii* Hatta is adopted for the small lamprey of southern Japan.

In the list of Japanese fishes the following new genera are indicated: *Ishikauia* (*steenackeri*), *Otakia* (*rasborina*), *Konosirus* (*punctatus*), *Bryttosus* (*kawamebari*), *Corusculus* (*Anthias berycoides*), *Eteliscus* (*Etelis berycoides*), *Insidiator* (*rudis*), *Trifissus* (*ioturus*), *Rhombiscus* (*cinnamomeus*), *Karcius* (*bicoloratus* = *scutifer*), *Usinosita* (*japonica*), *Zebrias* (*zebrina*), *Areliscus* (*joyneri*).

The two species referred to Gobio belong rather to Günther's genus Leucogobio. The specimens called *Apogon quadrifasciatus* belong to *Apogon notatus* (Houttuyn) = *semilineatus* Schlegel. Those recorded as *Sebastodes oblongus* belong to *S. mitsukurii* Cramer, which differs in the larger scales. The species recorded as *Chænogobius castaneus* is distinct from the latter species and is as yet undescribed. The genus Triænophorichthys, as Steindachner has shown, is identical with Tridentiger, and Trifissus is not different. In fact, later investigations show the identity of *Trifissus ioturus* with Steindachner's *Tridentiger bifasciatus*. D. S. J.

Fowler on Fishes of the Tropical Pacific. — In the *Proceedings of the Academy of Natural Sciences at Philadelphia* (1900, p. 493) Mr. Henry

W. Fowler gives a detailed account of fishes from Hawaii, Tahiti, and Samoa, in the collection of the Academy. Most of these were collected more than sixty years ago by the noted naturalists, Dr. John K. Townsend and Mr. Thomas Nuttall. Others were more recently obtained by Dr. William H. Jones and Dr. Benjamin Sharp.

The new species are the following. From Honolulu: *Lycodontis parvibranchialis, Echidna zonata, Stolephorus purpureus, Synodus sharpi, Hemipteronotus copei, Brotula townsendi;* from Samoa, *Mugil caldwelli.*

Mr. Fowler is very careful as to his nomenclature and synonymy, a sure sign of good workmanship in systematic zoölogy, and his conclusions seem everywhere tenable. The plates which illustrate Mr. Fowler's paper, eleven species in all, seem accurately drawn, but are not well reproduced.

It may be here noted that the name Stolephorus cannot be used for the great genus of anchovies, to which it has been of late years (following Bleeker) applied. Its type, *Atherina japonica* of Houttuyn, from Nagasaki, is not an anchovy, but the very common Japanese silver-sided sardine, Kibuna-iwashi, commonly known as *Spratelloides gracilis.* Stolephorus should therefore supersede Spratelloides. The genus of anchovies called Stolephorus should probably stand as Anchovia. The single species which Jordan and Evermann set apart under the latter name is probably not generically distinct. Perhaps all these species should be reunited under Engraulis, following Günther's view. The tropical anchovies have, however, a smaller number of vertebræ and a firmer texture of body than the species originally called Engraulis. I may note also the necessity of returning to Gymnothorax Bloch instead of Lycodontis. D. S. J.

Miall and Hammond's Harlequin Fly.[1] — This is a book about an animal that has figured prominently in histological work for a generation. It is a book that is intended to facilitate the study of Chironomus, especially for inland naturalists, to whom it is so readily available, by setting forth in detail its habits and life history, presenting a résumé of the studies hitherto made of it (chiefly on its salivary glands and its embryology), and adding many new and more or less interesting facts and observations. The chapter headings are as follows: Outline of Life History, and Relations of Chironomus to Other Diptera; the Larva of Chironomus; the Fly of Chironomus;

[1] Miall, L. C., and Hammond, A. R. *The Structure and Life History of the Harlequin Fly (Chironomus).* Oxford, The Clarendon Press. 8vo, iv + 196 pp., 129 figures.

The Development of the Pupa and Fly within the Larva; The Pupa of Chironomus; and The Embryonic Development of Chironomus. To this is added a brief appendix on methods, likewise intended to promote the use of Chironomus as a laboratory subject. The numerous figures are well selected and useful, but in their execution the best of them do not rise above mediocrity.

Incidentally there is described (on page 34) and figured the larva of Clinocera (Fam. Empididæ), a new type of dipterous larva with eight pairs of prominent abdominal prolegs. J. G. N.

Reactions of Protozoa. — In the Supplementband for 1900 of the *Archiv für Anatomie und Physiologie*, August Pütter[1] presents a most valuable contribution to our knowledge of the reactions of unicellular organisms. The fact that the reactions of these creatures to various stimuli are profoundly modified when the organism is in contact with a solid, is strikingly evident to any one that has studied the behavior of the Protozoa. Pütter has subjected to a thorough analysis this effect of contact of solids (thigmotaxis) and its interference with the operation of other stimuli, and the results form a contribution, an acquaintance with which is indispensable to all who wish to obtain an understanding of the behavior of these creatures. Exact observation of the actual movements of the organisms, close attention to the interrelation of structure and function, and careful analysis of the various factors involved, form the striking and valuable features of the paper, which stands in refreshing contrast in this respect to some of the recent papers dealing with the reactions of lower organisms. The paper is so full of detail, and casts light on so many observed phenomena, that it is impossible to give an idea of the results in a brief notice. In addition to a precise account of the thigmotactic reaction itself, the author deals particularly with the reactions to heat and to the electric current, as modified by the thigmotactic reaction. The observations on electrotaxis are in accord, in all essentials, with those set forth by Pearl in the *American Journal of Physiology* for July, 1900, and throw some additional light on this subject, especially on the subject of *transverse* electrotaxis. Attention may be further called to the fact that Pütter confirms for many Infusoria the method of reaction to a stimulus by turning toward a structurally defined side, as described by the reviewer.

[1] Pütter, August. Studien über Thigmotaxis bei Protisten, *Archiv für Anatomie und Physiologie*, Physiologische Abteilung, Supplementband, 1900, pp. 243–302.

By the work of Pütter another of the reactions of these organisms — thigmotaxis — is placed on a satisfactory scientific basis, and light is thrown on many other phenomena. H. S. J.

Notes. — Burchardt's recent article (*Jenaische Zeitschrift*, Bd. XXXIV, pp. 719–882) on the body spaces and connective tissue of Amphioxus is of general interest because of the accompanying bibliography, which is intended to be complete for this important and much studied animal. The list is arranged chronologically and includes some six hundred references. One is reminded of Baedeker on finding that important papers are indicated by an asterisk.

Metcalf ("Notes on the Morphology of the Tunicata," *Zoologische Jahrbücher*, Bd. XIII, 1900, pp. 495–602, Heft IV) gives us a paper extending over a wide range of morphological and systematic topics. A brief notice like the present one cannot mention all the results of interest contained in such a paper as this. Among them the following are perhaps the most important: The homology of the vertebrate hypophysis and the neural gland of the Tunicata is a "suggestion the truth of which, while it may be probable, is still insufficiently established." Reëxamination of the structure of the interesting deep-sea genus Octacnemus leads to the conclusion that its affinities are with those simple ascidians that reproduce by budding, rather than with the Salpidae, as supposed by Herdeman. It is proposed to institute a family, the Octacnemidæ, for it. A new species of the molguloid genus Bostrichobranchus, *viz.*, *B. molguloides*, is described.

A contribution to the postembryonal development of Molgula is made by Marc de Selys-Longchamps and D. Damas (*Arch. de Biologie*, Tome XVII, 1900, pp. 385–483). The development of the stigmata is studied with special care. Six pairs of protostigmata are recognized, the first two pairs forming simultaneously. The later multiplication and coiling up of the stigmata and the formation of the infundibulæ are followed out. The larval sense organ is found to persist into adult life in *M. ampulloides*. The study of the development of the sexual glands leads to the conclusion that there is no bilateral symmetry in the disposition of the germinative epithelium.

In studies on some distomes, Jacoby describes (*Arch. f. Naturges.*, Bd. I, 1900) a species, *Distomum heterolecithodes* Braun, which is remarkable for the fact that the vitelline gland, which is usually symmetrical, is developed only on one side of the body. In eleven cases studied the organ was sinistral, while in four the author found

a complete *situs inversus*, or, as Kowalewski has termed it, sexual amphitypy, in which the arrangement of organs is the mirror image of the normal condition. The same anomaly was found to occur in the following species in the ratio given: *Opisthorchis crassiuscula* (Rud.) 7 : 84, *O. poturzycensis* (Kow.) rarely; *O. albida* 16 : 68, *O. truncata* (Rud.) 6 : 50, *O. felinea* (Riv.) 8 : 100. Other cases from other species have been recorded by Stiles and Hassall, and Kowalewski regards it as a characteristic of the genus Opisthorchis. If this be true, it must still be remembered that it may occur in other genera also. Jacoby observed it in *Distomum lanceolatum*, which is not related to Opisthorchis but rather perhaps to *D. heterolecithodes*.

The nervous system of *Moniezia expansa* has been studied by Tower (*Zool. Jahrb.*, Abt. Morph., Bd. XII, pp. 359–384, 6 pls.). It is noteworthy that the physiological salt solution, so universally used, is harmful if the worms remain in it more than an hour. The author gives the formulæ of fluids successfully employed for transporting the cestodes, for keeping them alive in the laboratory even up to five days, and for fixing and staining the nervous tissues. In the scolex is present an anterior nerve ring with four small ganglia opposite the suckers, a pair of large cephalic ganglia connected with the ganglia of the anterior ring by four nerves and surrounded by the posterior ring which connects with the lateral lobes of the cephalic ganglia, and also by four small nerves with the ganglia of the anterior ring. These latter nerves are the beginning of the dorsal and ventral longitudinal nerves, while the prominent lateral nerves spring from the lateral lobes of the cephalic ganglia. No accessory lateral nerves were present. In each proglottid each lateral nerve bears an anterior lateral ganglion near the center and a posterior lateral ganglion near the posterior margin. From the former a transverse genital nerve arises, and from the latter a bunch of smaller fibers, together with a marginal nerve, which is recurrent, and the dorsal and ventral commissures which together constitute the nerve ring of each proglottid.

The Uncinariæ of the Canidæ and Felidæ and the Sclerostominæ of the Ruminants have been subject to a careful revision by Railliet (*Arch. Parasitol.*, Tome III, No. 1, 1900).

The distomes of the isolated genus Rhopalias St. and H. (Rhopalophorus Dies) have been restudied from Rudophi's and Diesing's types by Braun (*Zool. Anzeiger*, Bd. XXIII, pp. 27–29). Three species are reported, of which one is new, and the genus appears to be confined to the marsupials of South America. These forms are closely

related to the echinostomes, but the lateral lobes of the head, which are supplied with spines, have been transformed into a retractile proboscis.

An Atlantic "Palolo" is described by Mayer (*Bull. Mus. Comp. Zool.*, Vol. XXXVI, pp. 1–14, 3 pls.). The form, which is shown to be distinct from the Pacific species of similar name and habits, is named *Staurocephalus gregaricus*. It appeared in a dense swarm before sunrise on a single morning and discharged its sexual products with the coming of the sun under contractions so violent that the ripe segments were torn open. The author gives an interesting discussion of the advantages of this habit in shortening the egg-laying season, concentrating the breeding individuals and not only insuring more perfect fertilization, but also reducing the distance which the sperm must traverse in order to fertilize the ova; while the increased struggle for food due to the production of a large number of young larvæ is counterbalanced by the heavily yolk-laden egg of this species.

The Alciopidæ and Tomopteridæ of the Plankton Expedition by Apstein (*Ergebnisse der Plankton-Expedition der Humboldt-Stiftung*, Bd. II, H. b., 61 pp., 14 pls.) opens with an extended taxonomic account of the alciopids captured. The geographical distribution of these forms has been much extended, as appears from the tables given, which also show that the group belongs to warmer waters, with the exception of strays found in the northern branches of the Gulf Stream and of a single Antarctic species. Within the warm zones they appear to be generally distributed without special areas and are present everywhere in approximately equal numbers, as shown by the hauls of the vertical net. Among the tomopterids, however, a single species seems to occur only in the vicinity of land, though with an extended range, while the others are all true pelagic forms. The genus contains species found in cold waters, — those characteristic of warm regions and such as inhabit both. While moderately equally distributed, these forms do not manifest the uniformity noted for the alciopids.

BOTANY.

Some Recent Forestry Publications. — The interest in the preservation of the timber covering which still characterizes certain parts of the earth, and its renewal in denuded areas, which appears to be

spreading gradually in this country and which has long been recognized as economically important in many other parts of the world, is leading to the rapid appearance of handbooks and other publications, of varying degrees of excellence but all of utility. Notice has been made elsewhere of Mr. Gannett's magnificent treatise on our own forests,[1] which stands in a class quite by itself as a work of rare statistical and other practical value, and of the botanico-forestal books of Professor Sargent[2] and Miss Keeler.[3] The mail now brings an official handbook of Indian forestry, by R. Ribbentrop,[4] and a book by Abbot Kinney,[5] intended to awaken and spread popular interest in this subject on our Pacific coast.

Mr. Ribbentrop, who is Inspector-General of forests to the government of India, traces the history of forestry development in a British colony where, whatever else may be said, the home government has made continuous and intelligent effort to develop and conserve the rich endowment of nature; and the influence of this policy on the native governments is shown to be most encouraging.

Mr. Kinney, who has had ample opportunity to observe the reckless waste of timber in one of the grandest existing forests, analyzes the relations of forest preservation to the elements and the greed or carelessness of man, and presents an outline for a forest system for southern California. A number of specialists contribute chapters to his book on irrigation and the peculiar conditions appertaining to sand dunes. T.

Coulter and Rose's Umbelliferæ. — A revision of the Umbelliferæ of our flora, by Drs. Coulter and Rose,[6] constitutes the opening number of Vol. VII of the *Contributions from the United States National Herbarium.* Three hundred and seventy-one species, pertaining to seventy-eight genera, are included, with necessary

[1] Gannett, H. Forest Reserves, *Ann. Rept. U. S. Geol. Surv.*, Washington, 1900, vol. xx, pt. v. xviii + 498 pp., with numerous maps, charts, and process illustrations from photographs.

[2] Sargent, C. S. *The Silva of North America.* Boston and New York, 1890–1900. Twelve quarto volumes, with many plates, and to be completed in one or two additional volumes now in preparation.

[3] Keeler, H. L. *Our Native Trees and how to Identify Them.* New York, 1900.

[4] Ribbentrop, B. *Forestry in British India.* With a rainfall chart and three maps. ii + 245 pp. Calcutta, 1900.

[5] Kinney, A. *Forest and Water.* v + 247 pp., with numerous diagrams and half-tone plates. Los Angeles, 1900.

[6] Coulter, J. M., and Rose, J. N. Monograph of the North-American Umbelliferæ. vii + 256 pp., Pl. IX, ff. 65. Washington, 1900.

synonymy and description, and the essential fruit characters of the genera are clearly and accurately figured. In pleasing contrast with the habit of some writers, the authors give a full citation of the material that they have examined in the course of their study — on the satisfactory result of which they are to be congratulated.

Studies of Plant Life[1] is a laboratory guide for high schools, which represents the experience of three Chicago teachers. The twenty-four studies it contains, each consisting of directions and questions regarding easily obtainable material, are intended to supplement the botanical lectures or text-book work of a school year. Part I, made up of seventeen studies, deals mainly with Cryptogams; Part II is devoted to the organs of Spermaphytes and their modifications. Much use is made of the compound microscope and of comparatively inexpensive apparatus. In an appendix are given directions for twenty-four experiments illustrating nutrition, metabolism, growth, and irritability. Following this is an outline of a model field trip showing what may be done in the way of ecological study. At the end of the book comes an analytical key for the determination of one hundred seed plants of northeastern United States, which includes a short synopsis of forty-two families of angiosperms.

The book seems well calculated to direct young students along profitable and interesting lines of work, following present-day methods of teaching the "New Botany."

But few errors have been noticed, and these are for the most part such as any competent teacher may be trusted to correct before they are likely to become a source of trouble to pupils. Special attention should be called to the need of amending the study on seeds and seedlings. Here the most unfortunate misconception is the treatment of the maize kernel as a seed, the funiculus and hilum of which the student is expected to find. F. L. S.

Notes. — Professor Engler has issued the first of a series of "Ergänzungshefte" to the phanerogamic portion of Engler and Prantl's *Die Natürlichen Pflanzenfamilien*, containing additions for the years 1897–98. The publication of the regular fascicles of this

[1] Pepoon, Herman S., Mitchell, Walter R., and Maxwell, Fred B. *Studies of Plant Life*, a series of exercises for the study of plants. Boston, D. C. Heath & Co., 1900. 12mo, cloth, xii + 95 pp.

important work has now reached Lieferung 201, dealing with the Hyphomycetes.

"A Taxonomic Study of North-American Ranunculaceæ" is the title under which Dr. K. C. Davis publishes his thesis, submitted to the Faculty of Cornell University last June. It consists of a series of articles separately printed from various journals, some of which have already been noticed in the *Naturalist.*

A posthumous revision of the genus Matthiola, by Pascal Conti, accompanied by a portrait of the author, appears in No. 18 of the *Mémoires de l'Herbier Boissier.*

The Oxalidaceæ of Uruguay receive apparently careful treatment by Arechavaleta in fascicle 14 of the third volume of *Anales del Museo Nacional de Montevideo.* Thirty-five species are described.

A study of the leaf anatomy of the Melastomaceæ constituting the tribe Miconieæ, with reference to the classification of the plants, forms No. 19 of *Mémoires de l'Herbier Boissier.*

Bulletin 175 of the North Carolina Experiment Station contains descriptions of twenty-one species of Cratægus and eight species of Panicum, believed to be new.

Rubus idæus anomalus is reported from Vermont by Fernald in *Rhodora* for October.

Celtis pumila, the separability of which from the arboreous species of the Mississippi valley has long been in dispute, is critically considered, in connection with its allies, by E. J. Hill, in the *Bulletin of the Torrey Club* for September.

The Revue Horticole for October contains an interesting article by Bois on the Mexican forms of *Persea gratissima,* with a colored plate of one of the finer varieties.

The physiological differences between the sessile- and pedunculate-fruited English oaks are considered at some length by W. R. Fisher in the *Gardener's Chronicle* of September 22.

No. 14 of Dr. Holm's "Studies in the Cyperaceæ," in *The American Journal of Science* for October, refers chiefly to a collection of carices made in Alaska by Evans in 1897–98.

Part XIV of Kraenzlin's "Orchidacearum Genera et Species," recently issued, reaches page 896.

A monograph of the Erysiphaceæ, by Ernest S. Salmon, constitutes the ninth volume of *Memoirs of the Torrey Botanical Club*, bearing the date Oct. 4, 1900. Nine plates of details, containing 175 figures and a very full bibliography and host-index, with analytical keys for each genus, make the book easy to use.

A preliminary report on diseases of the red cedar caused by *Polyporus juniperinus* and *P. carneus*, by Dr. Von Schrenk, constitutes *Bulletin No. 21* of the Division of Vegetable Physiology and Pathology of the United States Department of Agriculture. The first of these fungi is described as new. The gelatine process-reproductions of photographic illustrations of the decayed timber are good examples of what may be done in illustration direct from the camera.

Professor Nelson publishes, as a separate from the tenth *Report of the Wyoming Experiment Station*, a preliminary list of the cryptogams of that state, exclusive of Pteridophytes.

An interesting article on the occurrence of mycorrhiza on Arctic plants is reprinted by Hesselman from *Bihang till K. Svenska Vet.-Akad. Handlingar*, Vol. XXVI.

The structure of the diatom girdle is discussed by Palmer and Keeley, in Part II of the current volume of *Proceedings of the Philadelphia Academy*.

Five new species and one variety, chiefly in Allium and Artemisia, are added to the Colorado flora by Osterhout in the September number of the *Bulletin of the Torrey Club*.

Part III of Thomas Howell's *Flora of Northwest America*, dated August 21, 1900, reaches part way through the Compositæ.

A "Botany of Southern California," by Charles Russell Orcutt, is begun in the *West American Scientist* for September.

A considerable number of new species of North-American plants are published by several writers in recent numbers of *Zoe*.

Professor F. Manson Bailey's contributions to the flora of Queensland, New Guinea, etc., continue to appear in current numbers of the *Queensland Agricultural Journal*.

Dr. Carreiro, the most active botanist now resident in the Azores, contributes a list of his recent discoveries to the October-November number of the *Bulletin de l'Académie internationale de geographie botanique*.

Volume VI of the "Flore de France" of Rouy and Foucaud, devoted to Rosaceæ, appears as the 1899 *Annales de l'Académie de La Rochelle*, and is ascribed to Rouy and Camus.

The public school department of Carthage, Mo., where nature study of the most practical kind has taken firm root through the efforts of Professor Stevens, the superintendent, has now begun the publication of a series of "Nature Study Leaflets," dealing with common objects.

Progress in American agriculture and the sciences upon which it rests is well sketched in the voluminous *Yearbook* of the United States Department of Agriculture for 1899, recently issued.

Part IX, recently published, completes the second volume of the *Bulletin of the Bussey Institution*, which has been in progress since the year 1877. A table of contents and an index make the subject-matter of the volume accessible.

Forestry in Sweden is reported on by General Andrews, late United States Minister to that country, in a Senate Document recently issued.

The conditions of success in grafting are discussed by Daniel in current numbers of the *Revue générale de botanique.*

Dr. P. Van Romburgh publishes an important paper on Caoutchouc and Gutta-percha in the Dutch Indies, as No. 39 of the *Mededeelingen* of the Buitenzorg Botanic Garden.

A biographical sketch, with portrait, of Klatt, whose writings on Iris and certain Compositæ are familiar to all working botanists, is reprinted by Voigt from the *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten* for 1898.

A portrait of the late Sir J. B. Lawes, whose field experiments on the physiology of agricultural plants, extending over many years, are known to all botanists, appears in *Science Gossip* for October.

PALEONTOLOGY.

Traquair's Presidential Address, Bradford, 1900. — The Zoölogical Section of the British Association, in its choice of Dr. Traquair for president, paid a graceful tribute to a scientist whose researches during the past thirty-five years have conduced more

to our knowledge of Paleozoic fishes than those of any other single investigator. And the propriety of electing a paleontologist to preside over its sessions is abundantly confirmed by the brilliant address of sixteen closely printed pages with which its sittings were opened.

In this essay Dr. Traquair has done for the class of fishes what Marsh attempted for American fossil vertebrates in general, and what Osborn accomplished for the Mammalia, in their addresses before the sister association[1] in this country some years ago; and these three summaries, taken together, constitute a very important chapter in the literature of vertebrate paleontology. Although not retrospective in an historical sense, Dr. Traquair's paper is in effect a clarified review, expressed in terms of evolution, of the leading philosophic deductions which the science of ichthyic paleontology has afforded up to the present time. Its significance consists in a clearer recognition of the relationships between different groups of fishes, together with a more precise indication of their lines of descent; and it contains also critical observations on various disputed points, such as the origin of paired fins, development of dental plates and dermal armor from shagreen-like scales, atrophy of the lower jaw and shoulder-girdle, modification of the caudal fin, and similar issues. And in conclusion it is stated that "the paleontology of fishes is not less emphatic in the support of the doctrine of descent than that of any other division of the animal kingdom"; also that "we do not and cannot know the oldest fishes, as they would not have had hard parts for preservation, but we may hope to come to know many more old ones, and older ones still, than we do at present."

The author devotes special consideration to those ancient forms whose structure he has so ably elucidated in earlier memoirs. As for the ostracoderms, a most enigmatical group, which he at one time supposed were derived from the primitive elasmobranch stem (owing to the resemblance of Thelodus scales to shagreen), an independent origin is now admitted to be possible; but the idea is discredited that they had any share in the evolution of more recent types of fishes. The Cœlolépidæ, to which "Cephalaspis as well as Pteraspis and its allies are traceable," were certainly shark-like

[1] Marsh, O. C. Introduction and Succession of Vertebrate Life in America, *Proc. Amer. Assoc. Adv. Sci.*, Nashville Meeting, 1873.

Osborn, H. F. The Rise of the Mammalia in North America, *ibid.*, Madison Meeting, 1893.

creatures, even if they were not offshoots from some primitive form of shark.

A novel and somewhat surprising interpretation of the equally problematical arthrodires is given, to the effect that they are teleostomes belonging to the order Actinopterygii. Newberry, it is true, imagined a resemblance to exist between Macropetalichthys and recent sturgeons; but we know now that this genus has nothing to do with coccosteans, and Newberry totally misapprehended its structure. The lack of a shoulder-girdle and lower jaw (properly speaking) in all coccosteans, — an anomaly which they share in common with ostracoderms, — and the peculiar arrangement and mode of growth of the dermal plates, are characters which, to our mind at least, are irreconcilable with actinopterygian affinities. Although functional "mandibles" and "maxillaries" are often present, yet they are evidently only modified dermal plates of the same nature as the body armoring; and the former are suspended in soft tissues without any articulation with the cranium or other bones whatsoever. They are no more homologous with the jaws of bony fishes than is the so-called "clavicular" with a pectoral arch. Bashford Dean would exclude arthrodires from fishes altogether, as Cope did the ostracoderms; and elsewhere a tendency may be noticed looking toward the revival of M'Coy's Placodermata.

Turning to the elasmobranchs, Dr. Traquair again surprises us by declaring that their paleontological history does not throw any definite light on the disputed origin of paired limbs or "on the question whether the so-called archipterygium is the primary form of paired fin in the fish, or only a secondary modification." Nevertheless, he cautiously admits that "the paired fins of the Upper Devonian shark, Cladoselache, as described by Bashford Dean, Smith Woodward, and others, seem to favor the lateral fold theory." Next follows a very interesting and very learned discussion of the Crossopterygii, the Dipnoi, and Actinopterygii, into which, however, space forbids us to enter. His conclusions regarding the first two groups are that "the Crossopterygii were not derived *from* the Dipnoi, and that the modern representatives of the latter group are degenerate forms; yet as to the immediate ancestry of the Dipnoi themselves and the diphyletic origin of the so-called archipterygium, we had best for the present keep an open mind." It need scarcely be added that this lucid and timely essay of Dr. Traquair's is of prime importance, not only to paleontologists, but to zoölogists everywhere.

C. R. E.

Triassic Fossils from Eastern Siberia.[1] — In this publication, Dr. A. Bittner has described the fragments of a pelecypod and beachiopod fauna from the Lower Trias of the Ussuri region, near Vladivostock, in eastern Siberia. Although the fauna is not rich, it is especially interesting, coming from the same formation from which Dr. C. Diener[2] has already described the characteristic cephalopod fauna.

While most of the species are new, it is surprising to find among them forms either identical or closely related to European forms, among which may be mentioned *Pecten conf. alberti* Goldfuss, *Pseudomonotis multiformis* Bittner, and *Myophoria conf. lævigata* Alberti, of which representative forms, or geographic variations, are found in the Werfen beds of the Tyrol.

Diener, on the other hand, found the cephalopod fauna of the Ussuri region absolutely different from that of the Tyrol, with its nearest relationships rather with the Triassic faunas of northern Siberia and India. It is, therefore, remarkable that a kinship with the European Trias should show itself in the pelecypod fauna, which also shows decided affinities with some forms in the Lower Triassic Meekoceras beds of southeastern Idaho, near Soda Springs. The cephalopod fauna of the Ussuri region is almost identical with that collected, but not yet described, by Professor A. Hyatt and the writer from Wood's Cañon near Soda Springs. These additional species will aid greatly in the correlation of the Idaho beds with those of the Ussuri region, and incidentally with the Mediterranean Trias.

J. P. S.

The Upper Paleozoic Fauna of Russia.[3] — In this paper N. Jakolew has added another link to the chain that connects the Upper Carboniferous faunas of Russia with those of America. Up to the present our knowledge of the gastropods of the Permo-Carboniferous, or Artinsk, beds of Russia has been scanty, but in this work we find a number of American species in the beds that lie above the Uralian and below the true Permian beds, analogous to the uppermost Missourian and possibly the lower part of the Wichita formation of the Mississippi valley region. The analogies between these transitional formations on the two continents have long been recognized,

[1] Bittner, A. Versteinerungen aus den Trias-Ablagerungen des Süd-Ussuri-Gebietes in der ostsibirischen Küstenprovinz, *Mém. Comité Géol. Russie*, vol. vii, No. 4, 1899.

[2] *Mém. Comité Géol. Russie*, vol. xiv, No. 3, 1895.

[3] Jakolew, N. Die Fauna einiger oberpalaeozoischer Ablagerungen Russlands. I, Die Cephalopoden und Gastropoden, *Mém. Comité Géol. Russie*, vol. xv, No. 3, 1899.

but every bit of additional evidence is welcomed. It all tends to show that in the time of the uppermost Coal Measures the great western ocean had extensions as far as the Mississippi valley on the one side, and to eastern Russia on the other, since the brachiopod, gastropod, and cephalopod faunas of the two regions have many species in common. Dr. Jakolew also announces the publication, in the near future, by Professor Tschernyschew, of an extensive work on the brachiopod faunas of the Upper Carboniferous of the Ural region, in which correlations will be made with the American formations and faunas.

J. P. S.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, RETIREMENTS, AND DEATHS.

EDUCATIONAL GIFTS.

American Museum of Natural History, $25,000, by the will of Oswald Ottendorfer; $5000, by the will of Henry Villard.

Amherst College, $75,000, from D. Willis James and C. M. Platt; $25,000, from other sources.

Augustana College (Illinois), $30,000, from E. C. and J. A. Erickssen.

Aurora College (Illinois), $50,000, from Andrew Carnegie.

Baptist Female University of Raleigh, N. C., $20,000, by the will of Chief Justice Faircloth.

Bates College, $10,000, by the will of Joseph Ricker.

Beloit College, a conditional gift of $200,000, from Dr. D. K. Pearson.

Bowdoin College, $20,000, by the will of Joseph Ricker.

Brown University, $250,000, from John D. Rockefeller, on condition that the endowment be increased to $2,000,000; $30,000, from two anonymous givers.

Carleton College, $50,000, from Dr. D. K. Pearson; $100,000, from other sources.

Carson and Newman College (Tennessee), a conditional gift of $15,000, from John D. Rockefeller.

Castine, Maine, $100,000, by the will of Charles F. Emerson, for a public library.

Chicago University, $1,500,000, from John D. Rockefeller; $25,000, from Leon Mandell.

Colorado College, $50,000, towards the completion of the scientific building.

Cooper Union (New York), $20,000, by the will of Oswald Ottendorfer.

Harvard University, $20,000, by the will of the late Governor Roger Wolcott; $50,000, by the will of Henry Villard.

Johns Hopkins University, real estate valued at $750,000, from William Wyman and Francis W. Jenks, upon condition that $1,000,000 be collected for the University. We understand that nearly the whole amount has been subscribed.

Lehigh University, $5000, from Warren A. Wilbur.

Malden (Mass.) Public Library, $125,000, from Elisha H. Converse.

New York Free Circulating Library, $20,000, by the will of Oswald Ottendorfer.

Northwestern University, $30,000, from Dr. D. K. Pearson.

Oberlin College, a conditional gift of $200,000, from John D. Rockefeller.

Rutgers College, $25,000, by the will of J. A. Vanderpool.

Syracuse Public Library, $200,000, from Andrew Carnegie.

Syracuse University, a conditional gift of $400,000, from John D. Archbold.

The University of Buffalo, $50,000, for the erection of the Gratwick Research Laboratory.

University of Pennsylvania, funds yielding $400, for a prize in the school of biology, from an anonymous friend.

University of Wisconsin, $1000, from Charles F. Pfister; $1000, from Fred Vogel.

Upper Iowa University, $225,000, from Andrew Carnegie.

Washington and Jefferson College, $60,000, from W. J. Thompson, for library building and equipment.

Wellesley College, $25,000, from H. H. Hunnewell, for the botanical department.

Wesleyan University, $2000, from G. W. Quereau, for the library; $1000, from C. H. Buck.

Yale University, $50,000, by the will of Albert E. Kent of Chicago; $80,000, by the death of B. D. Silliman; a conditional gift of $500,000, by the will of T. B. Winthrop; $68,152, from the estate of the late John De Koven; a part of the estate of the late Professor E. E. Salisbury, estimated at $150,000; $30,000, from Alfred Vanderbilt; $50,000, by the will of Henry Villard.

APPOINTMENTS.

Mr. Outram Bangs, assistant in mammalogy in the Museum of Comparative Zoölogy at Cambridge, Mass. — Professor Franz Boas, curator of ethnology in the American Museum of Natural History. — Dr. H. Boruttan, professor of physiology in the University at Göttingen. — Professor H. C. Bumpus, curator of invertebrate zoölogy and assistant to the president in the American Museum of Natural History, New York city. — Dr. A. Burian, docent for physiology in the University at Leipzig. — Mr. E. J. Butler, official botanist to the Indian government. — F. M. Chapman, assistant curator of mammals and birds in the American Museum of Natural History. — Dr. F. Czapek, docent for anatomy and physiology of plants in the German University at Prag. — Dr. Paul Eisler, professor extraordinary of anatomy in the University at Leipzig. — Dr. M. Fürbringer of Jena, professor of anatomy in the University at Heidelberg, as successor to Gegenbaur. — Myron L. Fuller, assistant geologist on the United States Geological Survey. — Joaquin Gonzalez Hidalgo, director of the Natural History Museum at Madrid. — Dr. Grabowski of Braunschweig, director of the zoölogical gardens at Breslau. — Dr. L. P. Gratacap, curator of mineralogy in the American Museum of Natural History. — Dr. Valentin Häcker of Freiburg i. B., professor of zoölogy in the Stuttgart Technical School. —

Miss Clara Hamburger, assistant in the zoölogical institute of the University at Breslau. — Mr. G. T. Hastings of Cornell, teacher of science in the English Institute at Santiago, Chile. — Dr. Erich Kaiser of Bonn, geologist of the Prussian geological survey in Berlin. — Dr. Friedrich Klein, professor extraordinary of physiology in the University at Kiel. — A. G. Leonard of the University of Missouri, professor of mining and mineralogy in the University of Idaho, at Moscow, Idaho. — Dr. G. S. Lingle, professor of experimental physiology in Rush Medical College. — Dr. Rudolf Martin, professor of physical anthropology in the University at Zürich. — Dr. Anton Nestler, professor extraordinary of botany in the German University at Prag. — Dr. F. Reinke, professor extraordinary of anatomy in the University at Rostock. — Dr. Arthur Robinson, professor of anatomy in King's College, London. — Dr. A. Sauer of Heidelberg, director of the geological survey at Stuttgart. — Dr. Marshall H. Saville, curator of Mexican and Central American archæology in the American Museum of Natural History. — Dr. F. Schenck of Würzburg, professor of physiology in the University at Marburg. — O. Schneider, geologist of the Prussian geological survey. — Dr. Oscar Schulz, privat docent for physiology in the University at Erlangen. — Dr. H. Stechmann, director of the Breslau zoölogical gardens. — Dr. L. Steigert, geologist of the Prussian geological survey. — Dr. Alexander Steuer, docent for geology and paleontology in the Darmstadt technical school. — Dr. H. Stille, geologist of the Prussian geological survey. — Dr. Fr. K. Studnička, docent for zoölogical histology in the Bohemian University at Prag. — Arthur Thompson of Oxford, professor of anatomy in the Royal Academy, London. — Dr. O. Tietze, geologist of the Prussian geological survey. — Dr. A. Tschermak, assistant in the physiological laboratory of the University at Leipzig. — Professor G. Vasseur, conservator of geology in the Museum of Natural History at Marseilles. — Professor A. Vayssiere, conservator of zoölogy in the Museum of Natural History at Marseilles. — Dr. Max Verworn, professor extraordinary of physiology and director of the physiological institute at the University at Göttingen. — Dr. A. Voelzmann, professor extraordinary of zoölogy in the University at Berlin. — Dr. Vogel of Hamburg, bacteriologist in the agricultural experiment station in Posen. — Dr. Charles H. Warren, instructor in mineralogy and geology in the Massachusetts Institute of Technology. — Dr. G. Wetzel, docent for anatomy in the University at Berlin. — Dr. E. Woloszczak, professor of botany in the technical school at Lemburg, Austria. — Dr. Fred. C. Zapffe, professor of histology in the medical school of the University of Illinois. — Dr. Theodor Ziehen of Jena, professor of psychology in the University at Utrecht. — Dr. W. D. Zoethout, laboratory professor of neurology in Rush Medical College.

RETIRED.

Sir A. Geikie, from the directorship of the geological survey of Great Britain. — Dr. Friedrich Goltz, professor of physiology in the University of Strassburg. — Dr. Georg Meissner, professor of physiology in the University at Göttingen. — Dr. E. von Mozsisovics of Vienna, from the position of vice-director of the Austrian geological survey. — Dr. Max Reess, professor of botany in the University at Erlangen. — John C. Smock, for ten years state geologist of New Jersey. — Dr. Filippo Sylvestri, from the position of chief of the zoölogical section of the National Museum of Buenos Aires.

DEATHS.

Dr. Theodor Adensamer, zoölogist, in Baden, near Vienna, November 16, aged 33. — Dr. W. von Ahles, emeritus professor of botany in the Stuttgart technical school, in August. — Dr. Richard Altmann, professor extraordinary of histology in the University of Leipzig. — F. R. Bedford, student of echinoderms, in London. — Dr. G. Boerlage, assistant director of the botanical gardens at Buitenzorg, Java, in September, while on an expedition to Ternate. — Dr. Breusing, assistant in geology in the Hannover technical school, while on a trip in Dutch Guiana. — Mr. Philip Crowley, entomologist and ornithologist, in London, December 20. — S. W. Egan, of the geological survey of Ireland, at Dublin, January 6. — Dr. Gustav Hartlaub, the celebrated ornithologist, at Bremen, November 20, aged 87. — Dr. R. Hegeler, privat docent for botany at Rostock, at Stuttgart, September 28. — Dr. George Duryea Hulst, the well-known entomologist, in Brooklyn, N. Y., November 5, aged 54. — Dr. William King, for thirteen years connected with the geological survey of India. — Dr. Philip H. Kirsch, ichthyologist, at Las Cruces, New Mexico. — Dr. S. J. Korschinski, botanist, at St. Petersburg, December 1. — Mr. R. D. Lacoe, the well-known collector of carboniferous fossils, at West Pittston, Pa., February 5. — John Henry Leech, entomologist, at Salisbury, England, December 29, aged 38. — Thomas Benton Marbut, geologist and mining engineer, at Esther, Mo., September 16, aged 29. — Dr. W. von der Marck, geologist, in Hamm, Germany, November 22, aged 86. — Dr. Paul Marès, botanist, May 21, 1990, at Mustapha, near Algiers. — Charles Marquet, entomologist of the Museum of Natural History at Toulouse. — John Potter Marshall, emeritus professor of geology and mineralogy in Tufts College, February 4, aged 76. Professor Max von Pettenkoffer of the University at Munich, by suicide, in January, aged 83. — Professor Dr. Adolf Pichler, geologist of the Tyrol, at Innsbruck, November 15, aged 82. — E. Roze, botanist, at Chatou, France, May 25, 1900. — Michael Edward, Baron de Selys-Longchamps, entomologist, well known for his studies of the Odonata, at Liège, Belgium, December 11, aged 86. — Dr. Otto Staudinger of Dresden, an eminent student of

Lepidoptera, at Luzern, October 13, aged 70. — Dr. Hermann Stechmanns, director of the Breslau Zoölogical Gardens. — Dr. Otto Martin Torell, director of the Geological Institute in Lund, Sweden. — Thomas A. Williams, botanist, connected with the United States Department of Agriculture, and formerly a student of Aphides, at Washington, D. C., December 23, aged 35. — Dr. Friedrich Anton Zürn, a well-known investigator of animal parasites, September 11, aged 65.

(No. 411 was mailed March 15.)